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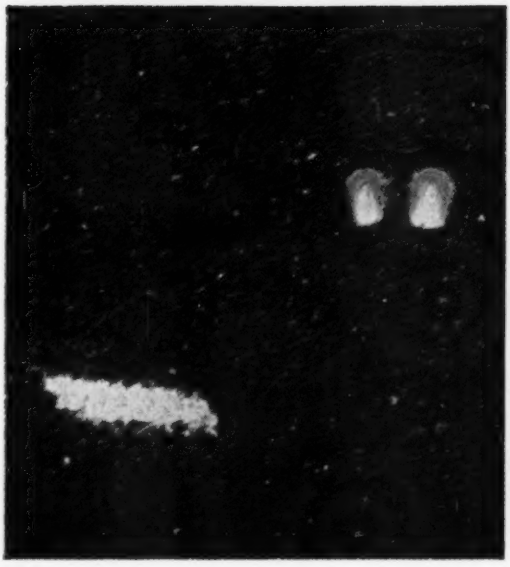

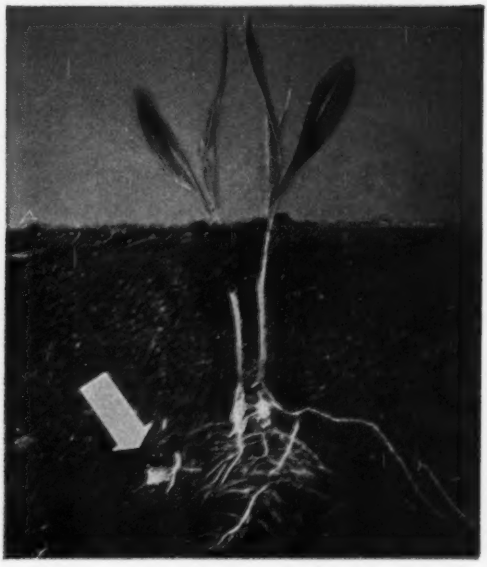

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ON THE COVER . . .

. . . We see the results of two different fertilizer placements. In one case, the placement was injurious, in the other it was productive.

Both seeds illustrated on the cover were planted the same day and pictured 9 days later.

In the two top pictures, when you put the fertilizer with the seed (left), the soluble salts in it limit germination by preventing moisture from entering the seed (right). Note the dark, moist band. This water cannot soak into the seed to start germination processes. Compare what happened to this seed with the seed below it.

In the two bottom pictures, the best results come from fertilizer placed below and to one side. Seed germinates quickly. Plant uses food inside the seed and tiny primary root brings in water from the soil. Side roots develop and grow out and down into the fertilizer. Plant has food available when it is ready to grow. The fertilizer, placed like this, really is a "starter."

Until relatively few years ago, we put little emphasis on where to place our starter fertilizer, so long as it got into the soil—sometimes with the seed, sometimes above it, sometimes directly below it. It didn't seem to matter too much, because the fertilizer was not concentrated enough to hurt the germinating seed and the applications not heavy enough to injure the early root growth—and it helped give the struggling young plant an early boost.

Today, the story is different. Our fertilizers are much more concentrated than they were just 15 years ago, our applications much higher, our planting speeds much faster. And when using worn, poorly adjusted split boot or single boot attachments, we tend unintentionally to place the fertilizer on the seed or so close to it that its germination is sometimes prevented, its growth often stunted.

Today, where we *place* our fertilizer can make the difference between a full stand and a poor stand and sometimes no stand.

For these reasons, *Better Crops* devotes this issue to placement of fertilizer—with special emphasis on row crops. And although we have tried to treat the subject as fully as our pages will permit, any reader attempting to put into practice any of the ideas expressed herein is urged to consult the professional agriculture workers of his area.

Photographs Courtesy of Successful Farming

Better Crops with PLANT FOOD

The Whole Truth
Not Selected Truth

SANTFORD MARTIN, JR., *Editor*

Editorial Office:
1102 16th Street, N. W.
Washington 6, D. C.

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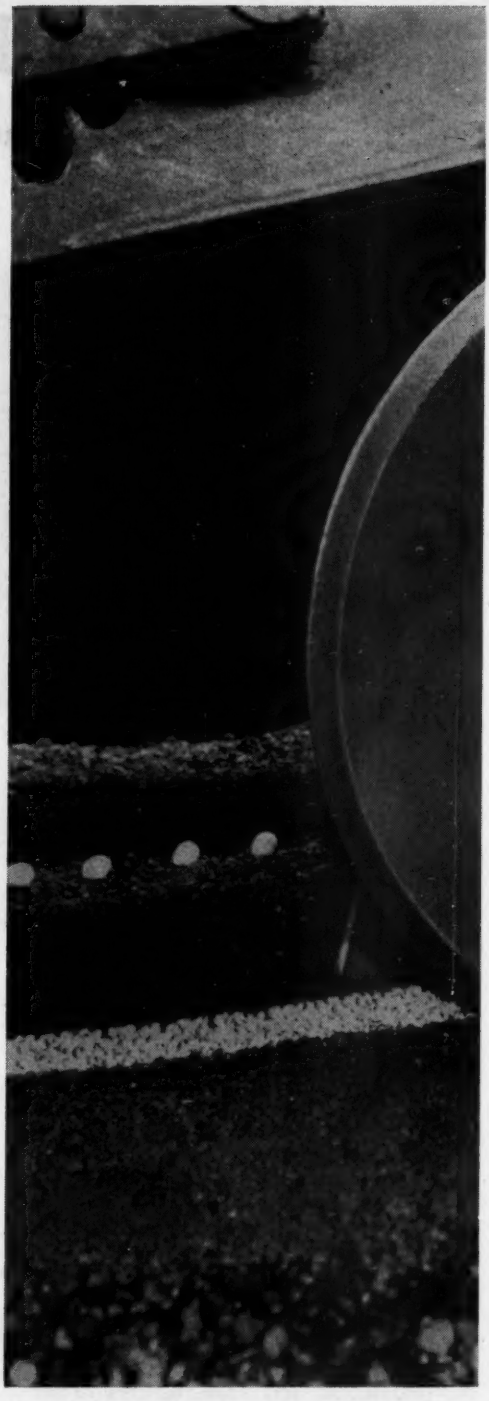

. . . a safe 2″ below, 2″ to side

Better Crops with PLANT FOOD

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In plant food replacement . . .

It's Placement That Counts

Jeff McDermid

(ELWOOD R. MCINTYRE)

Everyone and his brother have been talking about the proper placement of the high-power-mineral-salts fertilizers our farmers are using. Correct placement of those single bands of fertilizer means less burning of the tender seedlings . . . insures a better return for each dollar spent . . . puts the plant food down where the tiny feeder roots can gobble it up and where the moisture is handy to wash down the meal you give them.

Come to think of it, *placement* is really a big goal for us to shoot at in work or play.

There's placement of your house on solid rock, like the Bible says, but never on shifting sand or sinking mire.

Then we have personnel placement—the right man for the right job.

You want placement of a well where the water won't be contaminated with seepage from a barnyard on higher ground.

Old cronies sit hunched over a checkerboard, studying placement moves that will confuse and checkmate each other.

Race track devotees ponder and wonder about placement of their stakes.

Hunters depend on sharp placement of their shots.

And we all try to be discreet in placement of our savings—if we have anything left after placement of our orders.

"Replacement" is another word—just as big in many ways as "placement." In all of life's doings—comings and goings—what we replace or restore is more serviceable and spiritual than what we take and use up all by ourselves. Fertility of the acreages we own, conserving and improving them, the stewardship we practice—these rely on balanced replacement. Any soils doctor will back me up on that. But he'll be sure to get down on his knees in your field to point out that careless, injurious chemical placement with poorly performing machinery will cut your chances of fertility replacement and cripple your crops in the bargain.

Back of it all, erosion is the silent thief. It removes the finest, most fertile soil particles and replaces none. Instead of the original rich topsoil, the coarse, almost sterile subsoil remains, and cracks across the landscape wear a sardonic grin. With no replacement of organic matter, commercial plant food is lost and wasted. Though there may be no gullies, losses of forty tons of good soil per acre per year are common in the wake of the washing.

"IT'S HIGH TIME TO TOOT THE TUNE . . .

In a test made last year by a farmer in Chicago County, Minnesota, it was proved fertilizers can't do the whole job of boosting yields to high levels if the topsoil is gone. He compared yields of corn from badly eroded soil with yields from only slightly eroded land and from soil where the good top layers of somewhere above had been washed down and deposited. This last strip of soil was deep and rich. This gave him a chance to make a three-way test.

Ample starter fertilizer and weed killer were put on the *severely washed* area. The yield was 76 bushels per acre.

Fertilizer treatment and other factors were the same for the *slightly eroded* strip. Here the yield was 100 bushels.

But on the area where *topsoil had been washed in abundantly,* he used no fertilizer. And there his corn made 115 bushels per acre. That's about forty bushels better than the badly washed-out area could produce, even with painstaking fertilizer placement.

Such losses in topsoil need not cause poverty-stricken yields, regardless. A Michigan study has demonstrated that fields with all topsoil scraped clean can be restored to 95 percent normal productivity in four years of replacement.

What's to be done, many ask? The answer they give us is to use rotations, such as corn, oats, and two years alfalfa plus well placed fertilizer—or green manuring crops and stable manure, with adequate, well-placed plant food. Such stand-bys as contour tillage, strip cropping, diversion terracing, and grass waterways will prevent or change the rush

of freshest waters that flood away our land fertility. Then we're ready for both placement and replacement.

Farmers don't intend to burn the dickens out of their corn shoots by overfeeding them in the wrong way. But that's what often happens when growers don't follow recommendations about placement of starter fertilizers. Many of them also don't realize new, suitable equipment is available for proper single band application. They continue too often to rely on the old split-boot outfit, which proves unsafe in these times of fast planting rates, with more concentrated plant food combinations put on at greater strength.

It's high time the implement companies, the fertilizer folks, and the agricultural college extension soils men "strike up the band" to toot the tune of safer single band placement on row crops.

Mechanical perfections that get safe placement of fertilizers include a separate disc opener or a shoe that will adjust sideways and up and down. There are kits on sale that will convert the split boot on the planter to band placement equipment. Vigorous information efforts are

. . . OF SINGLE BAND PLACEMENT ON ROW CROPS"

being made to acquaint farmers with the latest devices to insure a safer laying down of the plant food in row-crop culture. Discarding the split-boot applicator is advisable, they inform us, because it often puts the fertilizer with the seed or even right above it. In case split-boot applicators must be used, the rule should be to put on moderate amounts while planting at low speeds, and maybe supplement the smaller amount of starter chemicals with broadcast applications. In fact, many soils low in fertility are best restored with some extra plant food replacement broadcast ahead of planting.

In the Midwest as a general thing, surveys indicate the amount of nitrogen plus potash has about doubled in 12 years. Just since 1949, the increase has amounted to approximately 63 percent in the East North Central states and by 83 percent in the West North Central region. The greater the power, the more care should be taken in placing.

Authorities also point out considerable trouble here and there with proper fertilization of small grains. To meet this situation, the need for better drilling equipment is being emphasized. Until grain drills that will properly separate the high-power fertilizer from the seed are in the hands of the farmers in the grain regions, the tendency will be to keep on recommending and using far less plant food than the amount considered adequate.

Establishing alfalfa in wide row corn is another new, seemingly practical method widely used. In one Wisconsin experiment, 300 pounds of 5-20-20 were drilled as a starter fertilizer in the 60-inch corn rows. This rate equals a concentration of 450 pounds of 5-20-20 per acre drilled in 40-inch rows. The fertilizer was placed one inch to the side

and 2½ inches below the seed with the adjustable fertilizer shoe on a tool bar corn planter. So variations of the safe method of placement will be found in the recommendations of soil workers, depending on the crops, the season, and the state of soil.

In many critical periods of change and adjustment, various forces of our country have stepped in to help farmers meet the problem with better, easier, cheaper methods. Sometimes these campaigns have met resistance—notably those affecting livestock disease eradication by herd slaughter. But given a sound approach and a frank warning of hazards, most farmers have accepted the new ideas and improved equipment with alacrity.

Although spring is gone and much fertilizer has already been applied, the shift from spring to fall in fertilizer and lime usage still gives everyone a chance to get in good licks on this latest of production problems. In effect, the five main attitudes of conservation will operate to see this through well. These attitudes so basic to modern farming are *open-mindedness, close observation, logical thinking, a sense of responsibility,* and *intelligent action.*

Soil replacement rests on placement—and growth on both!

MARKED DIFFERENCES IN EMERGENCE AND STANDS

The work by D. P. Satchell of Penn State, featured on pages 32-37, well illustrates the harmful effects of fertilizer placed too close to corn.

In a carefully controlled greenhouse study marked differences in rate of emergence and final stands were observed where different rates and kinds of fertilizer mixtures were precisely placed in bands (1) with the seed or (2) in bands one, two, or three inches to the side of the seed. Following is an example of the type of data obtained:

Fertilizer Treatment	Average Number of Plants (from 20 seeds)		
	10 days after planting	18 days after planting	Final Stand
Check - No fertilizer	8.5	16	16.5
15-60-60 lbs./a N, P_2O_5, K_2O:			
(a) with the seed	0	0	0
(b) in band 1 inch to side of seed	6	10	11
(c) in bands 2 or 3 inches to side of seed	Same as Check		

Although there were some differences in magnitude of the effect of different materials used, the above data illustrate the principal effects of placement methods.

Essentially all of the fertilizer materials, including phosphate, nitrogen, and potash, used alone or in complete mixtures, caused a delay in emergence and a marked reduction in final stands when applied in the row with the seed. All of the treatments caused a delayed emergence when applied in a band 1 inch to the side of the seed and in some treatments, there was a reduction in final stand from the 1-inch placement.

There was no effect of any of the treatments, however, upon either rate of emergence or final stand when the fertilizer was placed in a band two or three inches to the side of the seed. This study was not concerned with the depth of the band. However, other workers have generally found that a band to the side and approximately 2 inches below the seed level gave excellent results.

The Editors Talk

OF A WORKING FARMER

Even the ablest, most convincing agricultural scientist can't sell some farmers on adopting certain practices to get more profits out of their labors. But just let a neighbor—or a fellow farmer—get some startling results and the doubter starts peering through his fence. Nothing succeeds like success—to use a tired but true thought.

And that brings us to Alvan C. Thompson, owner of Thompson Farms in Bordentown, N. J., a successful farmer and former president of the National Vegetable Growers Association, who has succeeded by using modern farming methods. Of fertilizer placement, he says:

"The idea in fertilizer placement is to put the plant nutrients within the reach of plant roots, but not so close as to cause injury. We also want to have adequate amounts of all the necessary elements available, but not excessive supplies so as to avoid loss by fixation or leaching. Whenever large amounts of lime or fertilizer are incorporated with the soil such as is necessary when putting new soil or poor soil into condition to grow vegetable crops, it is very important to obtain a thorough mechanical mixture so as to have the material applied come into contact with as many soil particles as possible. This is a difficult problem and may take about two seasons. Thorough discing will help, but a better tool to use is a revolving or rotary type of tiller, in order to get a satisfactory mixture."

Although this issue is devoted largely to placement for row crops, Thompson's summary of the 8 principal ways to apply fertilizer effectively capsule the working knowledge of a working farmer—for fellow farmers:

- ***Broadcasting.*** **This may be done before or after plowing. The problem is to get a uniform distribution.**

- ***Band Fertilizer.*** **This method enables one to cut down on the rate compared to broadcasting. Seed drills and plant setters have special attachments to band fertilizer. To avoid burning, bands should not be placed too close to the row. Usually 2 to 3 inches to each side of the seed and about 3 inches below is about right.**

- ***Fertilizing the Cover Crop.*** **This enables a reduction in the quantity of fertilizer needed to grow the cash crop, since the cover crop predigests the plant food for it.**

- ***Topdressing and Sidedressing.*** **Since crops require only a small part of the fertilizer when small, it is often best to apply only part at planting time and the rest later in the growth period.**

- ***In Irrigation Water.*** **This is often a convenient way to apply fertilizer and usually produces an immediate response.**

- ***Solutions.*** **Plant starter solutions often are needed to give plants an early boost. Sometimes they are sprayed on the ground and plowed under and sometimes they are applied through attachments on planters and cultivators.**

- ***Foliar Sprays.*** **In periods following heavy rains and soil leaching, foliar sprays may often be valuable in getting the deficient nutrient into the plant quickly.**

- ***Gas.*** **Gas is usually applied under pressure and flows out into the soil under pressure. It is usually applied about 6 inches deep in the soil, and quite often before planting, or else midway between rows of corn.**

"Proper placement means putting the fertilizer in the soil in a way that minimizes injury to the seedling or plant and permits maximum nitrogen, phosphorus, and potassium to be absorbed at the time they are needed by the plant."

Proper Placement

BEGINS TO RANK WITH

Proper Amounts

IN THE MINDS OF TODAY'S FARMERS

By S. L. Tisdale **Director**

MANY a farmer, no doubt, has applied the rate of nitrogen, phosphorus, and potash recommended for high yields and been disappointed with his crop's response. Not understanding the failure, he has probably blamed the fertilizer itself—jeopardizing his farming future through antagonism toward a particular material that did not actually cause his troubles.

Many such experiences came from improper application or placement of fertilizer. Although the vigorous campaign to sell fertilizer materials has not always been matched by an equally vigorous campaign to ensure proper application, more emphasis is now being put on correct fertilizer placement. So feebly emphasized in the past, proper placement should begin to rank with proper amounts of fertilizer in the minds of today's farmers. Indications point that way.

Each farming situation is unique in certain respects. The fertilization practices on one farm may well differ from those on another. The grower himself must decide which practice he should follow.

Dr. Samuel L. Tisdale, Florida native, is Director of Soil Testing for the N.C. Department of Agriculture and Professor of Soils at N. C. State College. He earned his B.S. from Alabama Polytechnic Institute, his Ph.D. from Purdue. And for a brief time he was a TVA agronomist.

Here we see the effect of fertilizer placement on a stand of tobacco. The soil was Tifton sandy loam. Row 2: band 2½" to each side, 1" above root crown. Row 4: 2¾" band, 1" under roots. Row 5: Mixed with soil below and around roots. Row 6: In band 2½" to each side, 1" below root crown. Sidedressed with 400 lbs. fertilizer 20 days later.

Soil Testing **North Carolina Department of Agriculture**

To carry out these practices, he must know the principles of sound fertilization—in this instance, the principles of proper placement.

Proper placement means putting the fertilizer in the soil in a way that minimizes injury to the seedling or plant and permits maximum nitrogen, phosphorus, and potassium to be absorbed at the time they are needed by the plant. Just where and how fertilizer is placed to meet these two conditions depends on several factors.

A comprehensive look at fertilizer placement embraces three essential topics—placement under row crops; placement under forage crops, both for establishment and maintenance; and deep placement of fertilizers. Though the last two phases are interesting and important, the most pressing one to southern farmers is the first, or *proper placement of fertilizers* under row crops. For that reason, this article is devoted to this phase of the problem.

To begin with, the rooting zone of all plants must have adequate quantities of plant nutrients in the proper balance to produce maximum yields. For crops seeded annually, of course, preplant applications of phosphate, potash, and lime broadcast in quantities sufficient to bring the entire plow layer of the soil up to a maximum growth level supply the crop with adequate amounts of these materials. Because of its removal by leaching from many southern soils, nitrogen is not often applied successfully in this way.

In many acid southeastern soils, low in fertility and able to fix applied phosphate in an unavailable form, broad-

casting the fertilizer before planting may not be economically wise. In such soils, broadcasting a given quantity of fertilizer produces lower yields than placing the same quantity in bands near the seed. This is well illustrated by data from Tennessee shown in Table I.

Table I. The effect of broadcast versus row placement of fertilizer on the yield of corn, Tennessee (4).

At Planting	T. D.	Yield
20–40–40 in bands	40 lbs. N	52
20–40–40 broadcast	40 lbs. N	44
40–80–80 in bands	80 lbs. N	56
40–80–80 broadcast	80 lbs. N	49

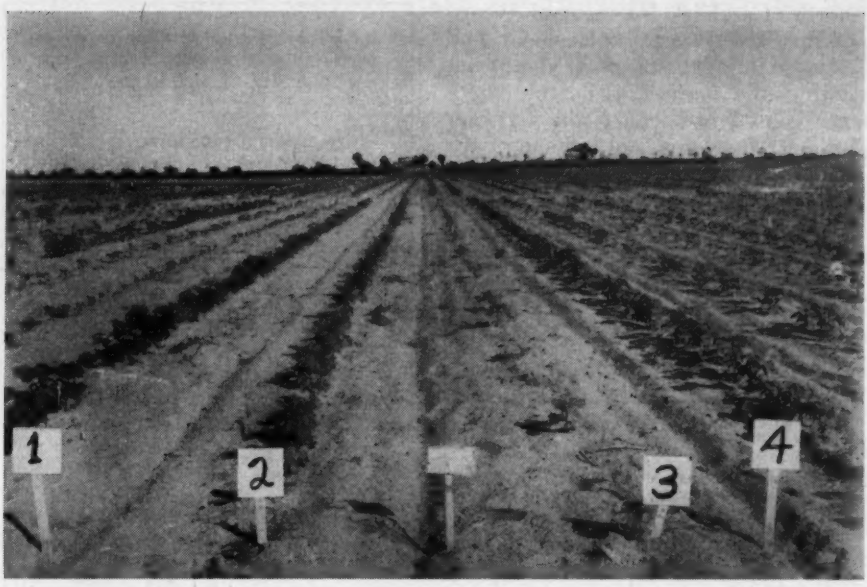
On soils of high fertility, yield differences between broadcast and banded applications would be diminished, as has been shown by Prummel (5). This is due to several factors. In the first place, soils with a high phosphorus and potassium level tend to fix in an unavailable form less of the applied phosphorus and potassium. Since banding the fertilizer reduces the contact between soil and fertilizer, less fixation will take place.

In low fertility soils, band placement would cause higher use of the applied fertilizer and hence higher yields. Another reason broadcast applications are less effective than band placement of the same amounts of phosphorus and potash on low fertility soils is the reduced contact that the root system has with the fertilizer elements. The lower the phosphorus and potash content in a soil, the less likelihood of a given phosphate or potassium ion being absorbed by the root system. When these materials are banded, however, root proliferation in the zone of fertilizer application might increase the total absorptive capacity of the root system, particularly during the early stages of growth. Absorption of these elements from the fertilizer band during early stages of growth is then greater, a fact borne out by many studies employing P^{32}.

A third factor contributing to the reduced efficiency of broadcast versus band placement of fertilizer may be related to the growth habit of the

Table II. The effect of fertilizer placement on the yield and stand of seed cotton, North Carolina (2).

Placement (32–64–32 at planting)	Plants per 50 ft. row	Yield lbs/acre
No fertilizer	366	913
In furrow with seed	64	705
Band 3.5 inches wide		
1 inch under seed	117	1,264
2 inches under seed	189	1,331
3 inches under seed	243	1,497
Band 1.5 inches to each side		
1 inch below seed	243	1,694
2 inches below seed	189	1,331
3 inches below seed	292	1,585
Band 3.5 inches to each side		
1 inch below seed	300	1,672
2 inches below seed	314	1,564
3 inches below seed	326	1,548



Here we see the effect of fertilizer placement on a stand of cotton. The soil was Norfolk sand to Ruston Loamy sand. Row 1: placed 2½" to sides and 2" below seed. Row 2: placed in bands 1½" to sides, 2" below seed. Row 3: placed in 1¾" band 3" below seed. Row 4: placed 2½" to sides, 2" below seed.

plant. With row crops, considerable time may elapse before the soil between the row is penetrated by the plant root system. If the fertilizer were applied broadcast and disked in before planting, considerable amounts of added nitrogen, and, on sandy soils, potash, could be lost by leaching under certain conditions before they were absorbed by the root system. Phosphorus would, of course, not be lost in this way because of its lack of mobility in soils.

Cotton

When concentrating fertilizer in bands, placing it too near the seed or transplant is dangerous. Soluble salts in the fertilizer go into solution and move with soil moisture. This movement, both laterally and vertically, can injure the seedling severely if the fertilizer is not properly placed. The influence of different band placement methods on stand and yields of cotton is illustrated in Table II.

Placement Very Important in Dry Spring

Yield and stand differences due to various methods of band placement are greater during years of unfavorable moisture conditions. For example, if considerable rain falls during and after germination, little difference in plant stands will probably occur among the various methods of band placements. But, after planting, if a rain penetrates the soil several inches and no more falls thereafter for a number of days, the movement of salts with the moving capillary water might cause great injury where the fertilizer is placed with, under, or above the seed. And the accompanying loss of moisture through evaporation tends to concentrate the fertilizer salts in the zone near the seedling.

Tobacco

Placement experiments with flue-cured tobacco were conducted in

North Carolina for several years. During "wet" years, placement had little or no effect on plant stand, but during "dry" years considerable injury was caused by placing the fertilizer too near the transplant. Some of the findings from this study are in Table III.

Table III. The effect of fertilizer placement on the stand of tobacco transplants, North Carolina (6).

Placement (36–108–72)	% Stand
All in row, not mixed	73
All in row, mixed	78
2 bands, 3 inches each side and 1 inch below	89

Peanuts

Fertilizer placement is also important to peanut production. Table IV illustrates again the importance of proper placement to high yields.

Tomatoes

Similar results have been obtained in Maryland with fertilizer placement under tomatoes. This is illustrated by data in Table V.

Bands to Each Side of and Below the Seed

Data from placement studies usually show the same pattern as that in these tables. Where the fertilizer is placed too close to the seed or transplant, moderate to severe reductions in plant stands occur, particularly during dry seasons. Because of this frequently demonstrated fact, the grower should adjust his fertilizer distributor to make maximum use of and prevent stand injury from his applied fertilizer. Otherwise he will not maximize the return on his fertilizer investment.

For most southern row crops, fertilizer placement meeting these two requirements is application in two bands about three inches to each side of and one to two inches below the seed or transplant crown. ◄◄◄

Table IV. The effect of fertilizer placement on the yields of peanuts, Virginia (1).

Placement (0–50–50)	Yield, lbs/acre
2 bands, 1½ inches each side, 2 inches below	1,391
2 bands, 3¼ inches each side, 2 inches below	1,609
1 band, 2 inches wide, 2 inches below	1,367
1 band, 2 inches wide, 3 inches below	1,525
1 band, 3–4 inches wide, 1 inch below	738

Table V. The effect of fertilizer placement on the plant stand and yield of tomatoes, Maryland (3).

Treatment	Stand, plants/plot	Yield, tons/acre
20–60–40 in row at planting 20–60–40 Sidedressing	384	1.95
20–60–40 2 bands 10 inches apt., 4 inches deep 20–60–40 Sidedressing at 6 weeks	2,309	7.69
20–120–80 2 bands 10 inches apt., 4 inches deep	2,352	7.94

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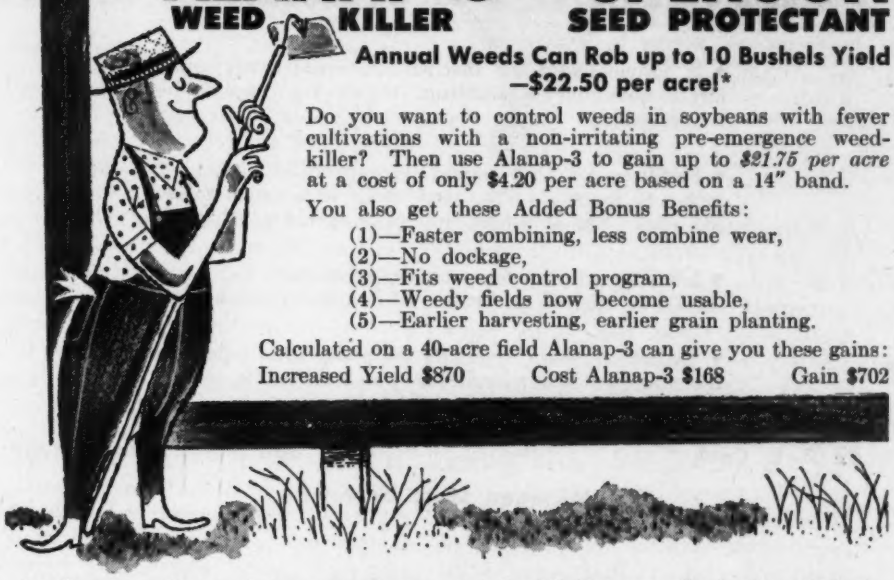

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producers of seed protectants, fungicides, miticides, insecticides, growth retardants, herbicides: Spergon, Phygon, Aramite, Synklor, MH, Alanap, Duraset.

FERTILIZER PLACEMENT FOR

- If agronomists knew that farmers could safely apply larger quantities of fertilizer, higher rates would be recommended.

- Fertilizer for corn should be applied in a band 2 inches to the side of the seed and 2 to 6 inches below the seed. The split-boot applicator is not satisfactory.

- Likewise fertilizer for potatoes, sugar beets, and beans should be applied to the side of and below the seed.

- Degree of water solubility of phosphorus influences the placement and particle size which should be used.

By R. L. Cook **Soil Science Department**

Michigan State University

FERTILIZER placement experiments have been conducted annually since 1934 by the Michigan Agricultural Experiment Station. Studies with potatoes even preceded that date. The results, reported regularly in the Proceedings of the National Joint Committee on Fertilizer Application, show proper placement increased yields and improved fertilizer efficiency.

Young seedlings should be well fed to promote rapid, vigorous growth but care must be taken to avoid injury to the germinating seeds and young roots. With most crops this means that fertilizers should not be placed in direct contact with seeds. In the early days this was accomplished by broadcasting the fertilizer ahead of planting. The advice to "work well into the soil before planting" was common, if not wise.

Band Applications Were Best for Row Crops

Certain soil minerals react readily with soluble phosphates applied as fertilizer. The resulting compounds are insoluble and very slowly available to plants. Formulated from superphosphate, the fertilizers of the "thirties" were powdered rather than granular and carried a high percentage of their phosphate in water soluble form. As a result, fixation was high.

Experiments recommended several times as much phosphorus as plants actually needed. Fertilizer placement experiments were designed to show where fertilizers might be placed to produce the desired starter effect while developing maximum efficiency. *Application in bands below and slightly to the side of the seed proved best for row crops.*

The first Michigan experiments conducted cooperatively with U.S.D.A. showed for potatoes it was best to place the fertilizer in two bands, one on either side of the row and on a level with the seed. Practically all of Michigan's potato crop is now fertilized in this manner. Planters have been perfected to do a good job of

Dr. R. L. Cook has been Head of the Soil Science Department at Michigan State University since 1953. Native of Michigan, he has worked on many phases of plant nutrition, including soil and plant analysis and deficiency symptoms. He has done much to foster interest in minimum tillage.

that placement method.

Before further cooperative placement tests were started with sugar beets and beans (1934), these crops were fertilized broadcast or by direct contact with seed. When the latter type of application proved very unsatisfactory for beans, the Michigan Station recommended the crop be planted without fertilizer.

Further experiments between 1934 and 1938, however, showed properly applied fertilizer was very profitable and "proper application" was in a single band one inch out and 1½ inches below the seed. The same location also proved right for sugar beets. (Fig. 1 shows the experimental planter used in those tests.) That was fortunate, because for years the two crops had been grown on the same farms and planted by the same drills. Only changes in seed plates were necessary to make the conversion.

Machinery companies heeded Station recommendations by marketing the first modern side placement beet and bean drills in 1940. The war delayed volume production, but since 1946 practically all of Michigan's sugar beets and beans have been planted in the recommended manner.

The Modern Era

Since 1945, fertilizer placement studies have centered around corn, vegetable crops, and legumes. During that time great changes have occurred in experimental methods and in fertilizer technology. Radio active phosphorus (P^{32}) has made it possible to trace the element from the fertilizer into the plant. Granular and liquid fertilizers have become common and concentrated materials have replaced the relatively low grades of pre-war days.

FOR SUGAR BEETS AND BEANS

Fig. 1. Fertilizer placement planter for sugar beets and beans. Designed by Glenn A. Cumings (deceased), U.S.D.A., in 1934 and used until 1940.

Furthermore, ammoniation and the development of new carriers have influenced the degree of solubility of the phosphorus in present-day solid materials. All these changes have made it desirable to take a new look at the old subject "Fertilizer Placement."

Corn

Prior to 1945, the beginning of the "Modern Era," Michigan soil fertility studies strongly indicated it didn't pay to apply fertilizer for corn. More fertilizer should be applied to the grain and legume crops, the recommendations said, but corn should receive only a small "starter" quantity. Early growth was always stimulated by a small amount of fertilizer at planting time.

In a rotation experiment conducted at the Ferden Farm (Sims clay loam) between 1933 and 1945, corn was grown each year. It received 100 pounds of fertilizer through a conventional split-boot planter. Six different grades were included in the experiment. A starter effect was always evident but yields were not increased. The corn followed alfalfa in a corn-oats-wheat-alfalfa rotation.

Similar results were obtained on other soils, ranging from sands to clay loams. Scattered throughout southern and central Michigan, the experiments were included in all systems of farming and in various rotations. Most of the trials had one thing in common. The fertilizer was applied through the split-boot applicators on the conventional corn planters of that day. One other method of application, plow-down, was employed on many of the fields. That method also failed to show evidence that fertilizers significantly increase corn yields.

Separate band placement had proved so satisfactory for potatoes, beans, and sugar beets that investigators decided to try the method on corn. Accordingly, the Agricultural Engineering Laboratory[1], U.S.D.A., again responded to a call for assistance and the machine shown in Fig. 2 was

[1] Prior to his death, Glenn A. Cumings was in charge of the U.S.D.A. work in this project. Since that time, assistance has been under the direction of Walter Hulburt, Agricultural Engineer, Beltsville, Md.

CORN PLANTER FOR BAND PLACEMENT OF FERTILIZER

Fig. 2. Corn planter for band placement of fertilizer. This machine made it possible to place one or two bands of fertilizer level with the seed or as deep as 6 inches below the seed. It was designed and constructed by Glenn A. Cumings (deceased), U.S.D.A., and Clarence Hansen, Michigan State University, in 1945 and was used through 1952.

born. This machine made it possible to place fertilizer in one or two bands at locations ranging from seed level to 6 inches below and at any desired distance out from the seed. Results from use of this machine were published annually in the Proceedings of the National Joint Committee on Fertilizer Application.

The experimental machine was so designed that the conventional split boot could be used for delivering fertilizer on the control plots. That method was used as the control. From the first, the yields definitely favored placement to the side of and below the seed. In many instances the results were better where the bands were 4 or 6 inches deep than where the shallower placement was employed.

From the start, it was evident one band was as good as two. In all the experiments with this U.S.D.A. machine, continuing through 1952, the two bands were at equal depths. *The split-boot applicator was always unsatisfactory.* This statement was made in an early issue of the Joint Committee Proceedings and in the 1953 issue of Michigan Extension Bulletin 159, "Fertilizer Recommendations for Michigan Crops."

The superiority of deep placement to the side of the seed over the method of plowing fertilizer under is shown in Fig. 3.

Later research on that same field showed corn roots were slow to take up the fertilizer nutrients that had been plowed under. This was due partly to the compaction of the soil between plowing and planting. Experiments now in progress indicate that plowed-under fertilizer may be more efficient when minimum tillage methods are practiced.

A quotation from the 1948 National Joint Committee bulletin follows: "Fertilizer at rates of application as high as 500 to 600 pounds per acre may be drilled in a continuous band approximately 2 inches to one side of the row in a depth zone about 2 inches below the level of the seed."

The background for this statement was the work done in Michigan in 1945, 1946, and 1947.

Fig. 3. "Fertilizer placement made the difference in this corn experiment in which an 8-8-8 fertilizer was applied at the rate of 1000 lbs. per acre. Left: Fertilizer placed in a band on the bottom of each furrow when plowing the land. Right: Fertilizer placed at time of planting in bands 2 inches to the sides of the row and 6 inches below the level of the seed."

PLACEMENT MADE THE DIFFERENCE IN THIS CORN

Two Bands at Different Depths

The planter shown in Fig. 4 was designed to place fertilizer in two bands but at different depths[2]. This made it possible to place starter fertilizer 2 inches below the seed and the balance, perhaps including most of the nitrogen, at a depth of 6 inches. The results have been very good, while helping avoid the inconvenience of sidedressing or pre-plant applications.

Experiments have shown that 16,000 or more plants of a high yielding hybrid require much greater amounts of plant nutrients than half that number of the older varieties. Also, the fertilizers must contain a large quantity of nitrogen or supplementary nitrogen must be applied as a sidedressing.

Vegetables

In the studies on fertilizer placement, vegetable crops have been neglected. This is unfortunate because, of all crops, vegetables are most responsive to fertilizer. And, no doubt, large quantities have been applied at the expense of efficiency and crop yields.

Michigan research men again cooperated with those from Beltsville to design the machine shown in Fig. 5. Experiments with onions and spinach on organic soils[3] showed fertilizer placement method actually caused yields to vary as much as 103 and 43 per cent respectively.

Complete fertilizers supplying 50 pounds N, 100 pounds P_2O_5, and 200 pounds K_2O were applied broadcast for onions or were banded 2 inches below the seed. Several combinations of treatments were tried. As an average for 1954 and 1955, highest yields (844 fifty-pound bags) were obtained when the potash was broadcast ahead of planting and the nitrogen and phosphate placed 2 inches below the seed. The next highest yield (788 bags) occurred when all the fertilizer was placed under the seed.

When the potash was drilled under the seed and the nitrogen and phosphate were broadcast, average yields dropped to 512 bags an acre, while

[2] Michigan Experiment Station Quarterly Bulletin 36: 317-319. 1954.

[3] Article 39-4 Michigan Agricultural Experiment Station Quarterly Bulletin 39: 25-35. 1956.

MODERN CORN PLANTER

Fig. 4. Modern corn planter fitted with large disks to make possible the placement of fertilizer bands at two levels. This mechanism was designed by Clarence Hansen and Robert Lucas, Michigan State University in 1953.

plots receiving all the fertilizer broadcast yielded only 414 bags.

Results with spinach were quite similar. As an average for the years 1952, '53 and '54, plots receiving 400 pounds of 5-10-20 through a grain drill before planting yielded 8.1 tons spinach per acre. When the same amount of plant food was placed one inch below the seed, the yield was 11.6 tons an acre. The two respective yields, when the same grade of fertilizer was applied at 800 pounds an acre, were 11.5 and 15.9 tons. The differences in yield were highly significant.

Sugar beets also yielded more when band fertilized on organic soils than when fertilized by the drilled ahead method. The comparative yields, when the fertilizer was 750 pounds of 0-10-30 an acre, were 15.3 tons from drilled-in fertilizer and 17.2 tons from fertilizer placed 2 inches below the seed.

To date, the results with carrots indicate very little response from variable fertilizer placement. Broadcasting or drilling the fertilizer has resulted in yields equal to band application. These results show that crops vary, so it is well to continue work with other crops. This is being done at the Michigan Station.

Legumes

Small seeded legumes (alfalfa, clovers, sweet clover) should be well fertilized at seeding time. This has been recognized for many years, as stated in 1944 by Cook and Millar.[4] One must be careful, however, to apply the fertilizer in a way that will get efficient use of the fertilizer without injuring the seed.

Band seeding is widely recognized as the best way to establish a legume seeding. The seeds are dropped on top of the soil directly over a band of fertilizer which is covered by at least one inch of fertilizer-free soil. The seed should be pressed down by means of a packer wheel. No other means should be taken to cover the seed. This method has been used

[4] Michigan Agricultural Experiment Station Special Bulletin 328. 1944.

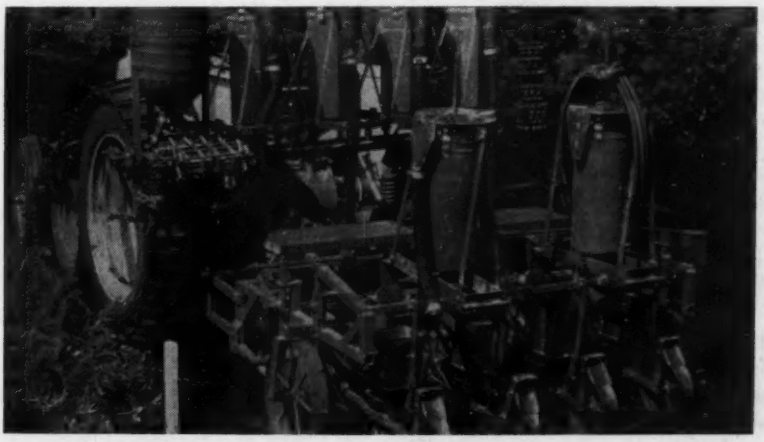

Fig. 5. Fertilizer placement drill designed especially for experiments with vegetables on organic soil. This drill is equipped to apply liquid and solid fertilizer in bands at various depths below the seed and at various distances to the side of the rows. Note the tank and top delivery hoppers mounted on the rear of the tractor. The smaller hoppers on the 4-row planter are for applying minor elements and insecticides.

FERTILIZER PLACEMENT DRILL

successfully on all types of Michigan soil.

Topdressing is a satisfactory method of applying fertilizers for established stands of alfalfa. Lawton, et al.[5], used radio-active phosphorus techniques to study the effects of placing phosphate fertilizers on the soil surface in established stands of hay and at various depths to 36 inches. A glass tube was used to place the fertilizer below the surface. Where fertilizer phosphate was broadcast on April 24 on the surface of Berrien sandy loam soil, a sampling on May 17 showed that 44 per cent of the plant phosphorus came from the fertilizer. On that same date only 15 per cent of the plant phosphorus came from fertilizer which had been placed 3 inches deep, also on April 24. Where fertilizer had been placed 12 inches deep the figure dropped to 7 per cent and to 2 per cent for the 36-inch depth.

These data show that quickest results from the applied fertilizer occurred with surface applications.

When fertilizers were placed 12 inches or below, the plants never contained enough fertilizer phosphorus to equal more than about 10 per cent of the total. On Conover loam soil, the deeper placements were even less effective than on the Berrien sandy loam.

Apparently the effective feeder roots of alfalfa were largely in the surface 6 inches of soil. Perhaps in looser subsoils, they might develop at greater depths. The supply of oxygen is probably the deciding factor.

Wheat

Fertilizers in contact with wheat seed may be injurious during dry weather. The conventional grain drills place fertilizer in this manner. The 1957 yields in Michigan and Ohio will be drastically reduced as a result of delayed emergence and poor stands. This resulted from the low soil moisture during and after planting.

Two experiments now in progress will show how serious the injury may be in terms of yields. One is on Sims clay loam in Saginaw County and the other on Conover loam on the University farm. 5-20-20 fertilizer was applied at rates of 300, 600, and 900 pounds per acre, *in contact with the seed and to the side and below the seed.* The latter placement was made possible by use of an experimental U.S.D.A. drill, designed and constructed at the Agricultural Engineering Laboratory in Beltsville, Md.

On both soils, stand was injured by 300 pounds of fertilizer in contact with the seed and was very seriously injured by the two larger quantities. Stands were perfect when the fertilizer was placed in bands separate from the seed, even where the rate was 900 pounds an acre.

Also included in these experiments are some treatments where the potash was drilled ahead of planting and the nitrogen and phosphate placed with the seed. Ammonium and di-ammonium phosphates were used as the sources of nitrogen and phosphorus. Stands were not seriously affected where the potash was drilled before planting. This kind of split application needs further study. Perhaps it should be recommended where soil type and soil test indicate a need for more than a medium amount of fertilizer.

In Michigan that amount might well be set at 50 to 60 pounds of $N + K_2O$. The quantity of P_2O_5 is less important so far as toxicity is concerned.

Water Solubility and Particle Size

When a fertilizer granule containing water soluble phosphorus is placed in moist soil, 50 to 80 per cent of the phosphorus will move out of the granule in 24 hours. However, it will move away into the soil very slowly. Thus, as long as the soil is not stirred,

[5] Soil Science Society America Proceedings 18: 428-532. 1954.

a highly concentrated "shell" of soluble phosphorus remains around the granule.[6] Fixation of such phosphorus into unavailable forms is slow, varying inversely with the size of the granule.[7]

The experiments which made these statements possible about the migration of phosphorus from granules into soil were conducted with tagged phosphorus (P^{32}). Further studies with this research tool have shown that a strong interaction exists between degree of phosphorus solubility, particle size, and method of placement.

When *powdered* fertilizer was well mixed with soil, the percentage of the phosphorus in water soluble form had very little effect on yields or on the amount of fertilizer phosphorus which entered the plant. Apparently the phosphorus from the fine particles of fertilizer contacted so much soil that very high fixation occurred (probably as hydrated iron phosphates).

When *granular* fertilizer was well mixed with soil, the percentage of the phosphorus in water soluble form *did* have a marked effect on the percentage of fertilizer phosphorus absorbed by the plant and *did* have a marked effect on yields. To be satisfactory, granular material should have 40 to 60 per cent of its phosphorus in water soluble form. The experiments have shown that granular materials containing but a small percentage of phosphorus in soluble form contact too little soil to be effective as starter fertilizer for rapidly growing plants.

When granular or powdered fertilizer was banded in soil, the uptake by plants of the fertilizer phosphorus increased directly with an increase in the degree of solubility of the phosphorus in the fertilizer. Likewise, the yields increased with the same increase in degree of solubility of the fertilizer. For maximum efficiency, fertilizer to be applied in bands should contain not less than 40 per cent of its phosphorus in water soluble form.

The experiments showed definitely that fertilizers which contain no water soluble phosphorus should be thoroughly mixed with soil and should be powdered rather than granular.

Liquid vs. Solid Fertilizers vs. Placement

As already stated, water soluble phosphorus soon becomes insoluble and to quite an extent unavailable to plants when mixed with soil. There are two ways of avoiding extreme fixation of the phosphorus in soluble solid fertilizers. Granulation provides the first method and banding the second. Both methods are effective because they reduce the area of fertilizer-soil contact.

It is not possible, of course, to granulate solutions. Then the only method of reducing fertilizer-soil contact is to place the solution fertilizer in bands. Experiments have shown that this is true. Radioactivity counts made on 8-week-old corn plants were about equal where liquids and solids were banded at planting time. Likewise the counts were about the same where the two materials were thoroughly mixed with the soil before planting. *However, the counts were three times as high for both liquids and solids where the fertilizers were placed in bands.*

In this comparison, the same formulations were involved, as the liquids were obtained by dissolving the solid fertilizers in water. In comparing solid and liquid fertilizer it is essential the solid material have a high percentage of its phosphorus in water soluble form and that the two materials be placed in the same location relative to the seed.

Liquid fertilizers applied as spray cannot be expected to increase yields as much as the same plant foods ap-

[6] Soil Science Society America Proceedings 18: 26-32. 1954.

[7] Farm Chemicals: 44-46. April 1955.

plied in bands. In a 1955 experiment on a sandy loam soil, 50 pounds of P_2O_5 were sprayed just as corn was emerging. On comparative plots, the same amount was injected in a band close to the row. The yields were 56.0 and 72.9 bushels per acre, with the higher yield caused by band treatment. In spray treatment, much of the phosphorus must have been fixed into forms not available to the plants.

In 1956, liquid and solid fertilizers were compared by application in bands below and to the side of the corn row. Application was at planting time. On Hillsdale sandy loam, the liquid fertilizer resulted in about the same yield as the solid material; yields were 73.2 bushels as compared with 71.3. On the Kalamazoo soil, the yields were 64.7 and 67.6 bushels, with the higher yield coming from the plots receiving solid material.

Summary

The Michigan Station has conducted fertilizer placement tests each year since 1934. The early work was done when all fertilizers were formulated from superphosphate, a carrier containing most of its phosphorus in water soluble form.

The early tests showed that to avoid injury to seeds and seedlings and to obtain greatest efficiency in fertilizer use, fertilizers for potatoes, beans, and sugar beets should be applied in bands to the side and below the seed. The experimental work was done in cooperation with the Agricultural Engineers from U.S.D.A.

Corn experiments conducted during the period 1945 to 1952 showed that fertilizers for corn should be applied in a band 2 inches to the side of the seed and 2 to 6 inches below the seed. During that research period, the control treatment was application through the split boot. The results verified the suspicions of a decade, that *the split-boot applicator was not satisfactory.*

Good results were obtained with a planter which placed fertilizer in two bands at different depths—the shallow band (2 inches below the seed) for starter fertilizer and the deep band (6 inches below the seed) for the remainder. Thus it was possible to avoid pre-plant and starter fertilizer inconveniences.

Band applications separate from the seed have given good results with vegetables, legumes, and small grains. Tagged phosphorus techniques showed that more fertilizer phosphate entered young plants from banded and granulated fertilizers than from powdered fertilizers mixed with soil.

Interactions were found between degree of water solubility, particle size, and method of placement. The results prompted the conclusions that (1) only fertilizers high in degree of water solubility should be granulated, (2) solid fertilizers high in degree of water solubility and liquid fertilizers should be banded, (3) water insoluble fertilizers should be mixed with soil and should not be granulated, (4) solid fertilizers high in degree of water solubility should be granular or pelleted if they are to be bulk spread.

Improvements in fertilizer distributing machinery are badly needed. If agronomists knew that farmers could safely apply large quantities of fertilizer, higher rates would be recommended. This is especially true with corn and small grains. ◄◄◄

103 PER CENT DIFFERENCE

A method of applying fertilizer makes as much as 103 per cent difference on onion yields and up to 50 per cent on spinach yields according to scientists at the University of Michigan. Their experiments, on muck soils, show that fertilizer for these two crops should be placed in a band two inches below and one inch to the side of seeds.

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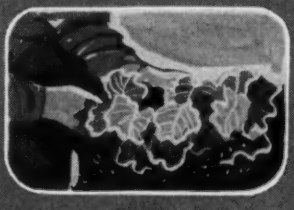

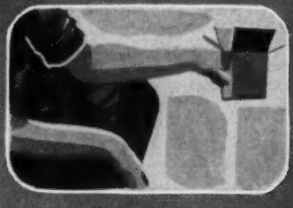

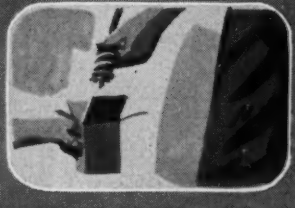

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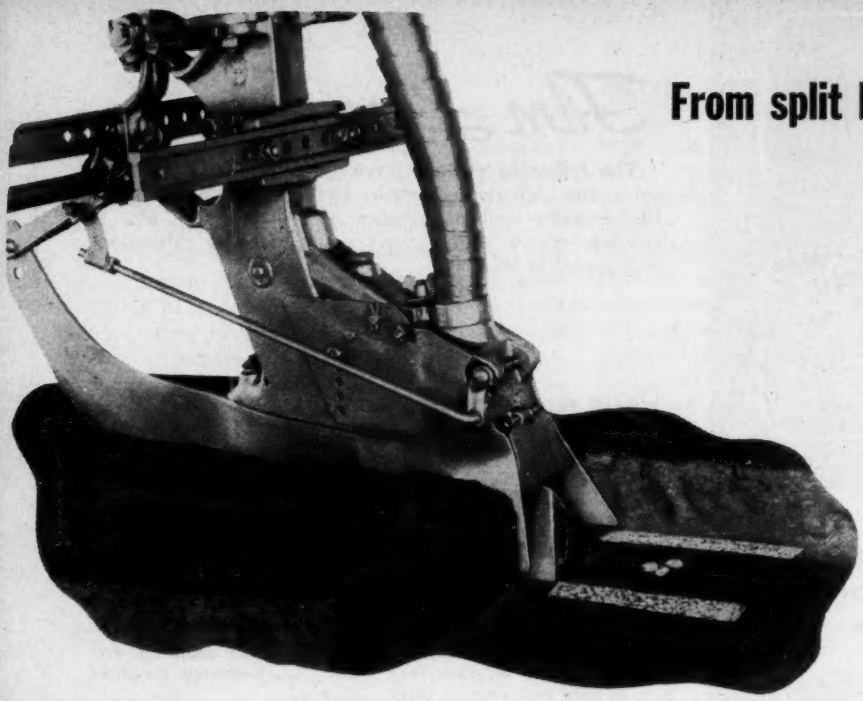
From split boot to single

PLACEM



For years, split boot equipment, as shown above, has been used to place planting fertilizer—usually in two bands above the seed or in two bands on each side at seed level. Above the seed, the plant food is out of reach for early plant growth. On seed level—with today's faster planting speeds, more concentrated fertilizers, and higher applications—the fertilizer often ends up with the seed and kills germination.

Many successful farme
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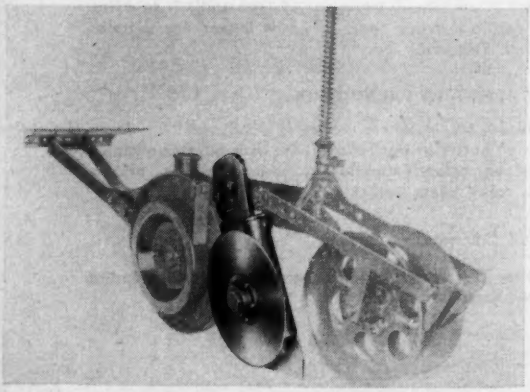
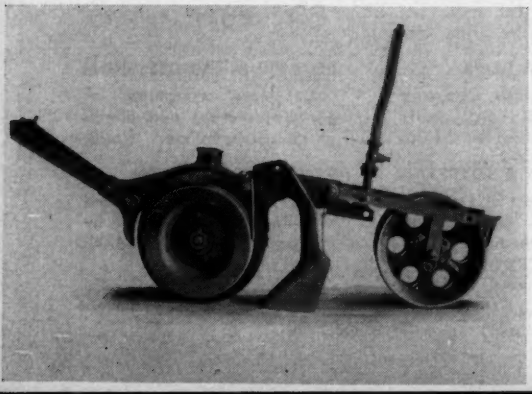
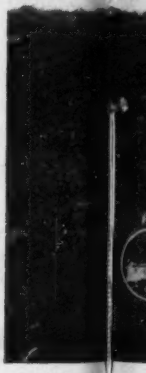


The disk fertilizer applicator is shown attached for use with a double disk opener on the planter.



The round nose fertilizer applicator is shown attached for use with double disk openers.



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converting to such units, farmers
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and seed in a part of the row
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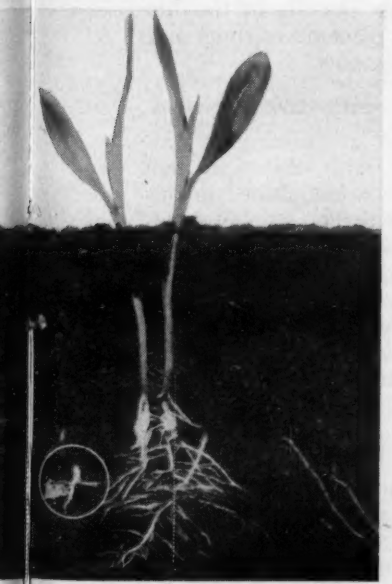
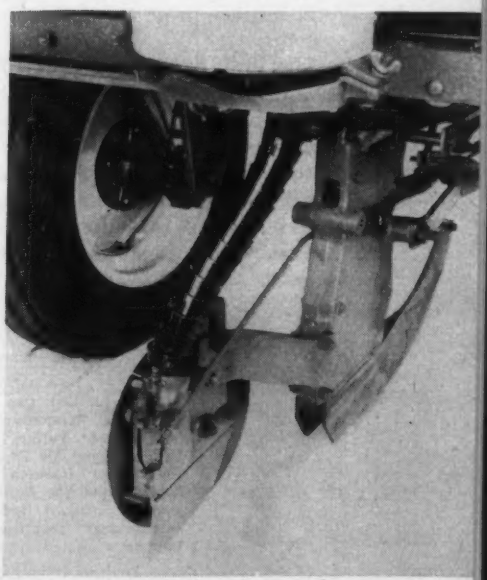
planting speed—and check it
y against obstacles that may throw
ener out of position.

The trend today in fertilizer placement for row crops is toward single band placement, as shown above—a safe, efficient way to place planting fertilizer. The single band is about 2 inches to the side, 2 inches below the seed. It is safe because the fertilizer salts do not contact the germinating seeds or tender seedlings . . . efficient because the fertilizer is placed where the feeder roots can soon reach the plant nutrients and the band is down where the soil is more likely to be moist. Such attachments are on the market, as shown in the lower part of this spread.



esult from starter fertilizer come from band 2" below, 2" out (shown in circle)—taken 9 er planting seed. Here the plant has food when it is needed. Here fertilizer is a "real



One kind of attachment for efficient single band placement of starter fertilizer is the single disk opener shown above, used with a runner type opener on corn planter.

CERTAIN PRINCIPLES

For Getting Effective Nutrient Use from Fertilizer Bands

- **Place it to intercept secondary roots**
- **Keep soluble salts low around seed**
- **Place off to side and below seed level**
- **Watch root development in band**
- **Keep phosphate and nitrogen together**
- **Use band to add nutrients**

A LARGE proportion of mixed fertilizer used in the United States is applied in localized zones in the soil. The majority of this banded fertilizer is applied at planting time. Its primary objective is to get the crop off to a good start. And for this reason it has often been called "starter fertilizer."

Many times, however, the rates of application are such that in addition to providing a good start for the crop the fertilizer also contributes to the total fertility program of the cropping system.

The bulk of the mixed fertilizer is used on cereals—corn, wheat, and oats. These crops of the grass family are notoriously poor feeders for phosphate during their early growth. Row fertilizers are important in getting these crops off to a good start.

There are four distinct growth periods in the life cycle of plants. Using corn as an example, there is the seedling, or formative period, consisting of about one month from emergence of the corn; then the vegetative period, when corn makes its rapid growth during a period of about three weeks; then the flowering period, when tassels and shoots appear, lasting another two to three weeks; then the period of maturation when the ears are filled.

Each of these periods in the life cycle of a corn plant has distinct and different requirements.

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Seedling or Formative Period

Row fertilizer at planting is concerned largely with the formative period. Much is accomplished in this important first month. One morphologist describes the status of corn at the end of one month as follows:

"All of the nodes, internodes, leaves and axillary buds the plant will ever have are determined and present in a state of partial development; the tip meristem of the stem axis has been transformed into the primordial tassel; approximately 90% of the vascular bundles present in the lower nodes at maturity are present in lower nodes at the end of the formative period; and commonly the root system consists

This picture shows starter response from fertilizer. The rows on left had no fertilizer, the ones on right 3-9-27. Row fertilizer at planting is concerned largely with the seedling stage—put to the side and below the seed level, where it will intercept secondary roots, where soluble salts are kept low around the seed.

By A. J. Ohlrogge M. H. Miller W. G. Duncan
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of five or more whorls of roots which have their size and conductive capacity fixed."

This is a most important period of plant growth. The embryo in the seed has a fixed yield possibility which the farmer cannot change. It is genetically fixed. This yield possibility for corn, with adequate population, may be 200, 250, 300 or more bushels per acre. The ultimate figure with an ideal environment is still hypothetical.

As the seed germinates, the farmer can try to eliminate the factors that hold the yield possibility of the environment far below the genetic yield possibility of the crop. This is done through fertilization, weed control, and all the other practices contributing to yield.

Where to Apply the Fertilizer

The band of fertilizer occupies a very small volume. Volume, of course, varies with the kind of salt, method and rate of application, and the texture of the soil. But with average fertilization of silt loams, the effective volume is often less than an inch square in cross section. It occupies between 1/100 and 1/1000 of the root volume, depending on the stage of development of the crop.

Surely such a small volume of fertilizer must be placed where the roots will come in contact with the band. It must intercept the growing root. Roots do not go out of the way to reach fertilizer. With these principles in mind, let us consider how the young corn roots develop.

On germination, the first primary root takes a direct path downward, since it is very geotropic. If we want this root to take up fertilizer, the band should be placed directly below the seed. But this is not an effective placement for mixed fertilizer, because the result depends on water movement in the soil. If no rain follows planting, drying soil will move the fertilizer salts up around the germinating seed. The salts will then "dry out" the seed, causing poor germination and stands.

If the salts remain where placed, the primary and only root at this stage will be stopped in its elongation by the salts, thus slowing the growth. In seasons of much rainfall after planting, however, the soluble salts will be moved out of the root zone and growth will be normal. Placement directly below the seed, then, is not a reliable fertilization technique.

It is not necessary to feed fertilizer to this primary root since the seed reserves take care of this initial growth. Only a few days after the primary root comes out, a series of secondary seed roots come out above the primary seed root. These have a much less geotropic effect and grow outward and downward. When placing fertilizer it is necessary to place it in the path of these later developing secondary roots. Roots do not grow to fertilizer. The fertilizer should be placed below the point of origin of the roots from the stem, since the roots grow down.

Fertilizer off to the side of the seed and below seed level represents almost ideal placement. This is a safe and efficient placement.

Root Proliferation in Band Essential

Since the fertilizer band volume is very small, it is inconceivable a plant could utilize very much fertilizer when less than 1% of its root surface is in contact with the available nutrients of the fertilizer. This fact sets up the next requirement for efficient use, the rapid development or proliferation of roots within the fertilizer band.

What Causes Root Proliferation in the Fertilizer Band

When the root hits the band, it must develop rapidly—similar to a willow root entering a sewer tile. Masses of roots develop to plug the tile, even though the entry root may be only one in number and less than a tenth of an inch in diameter.

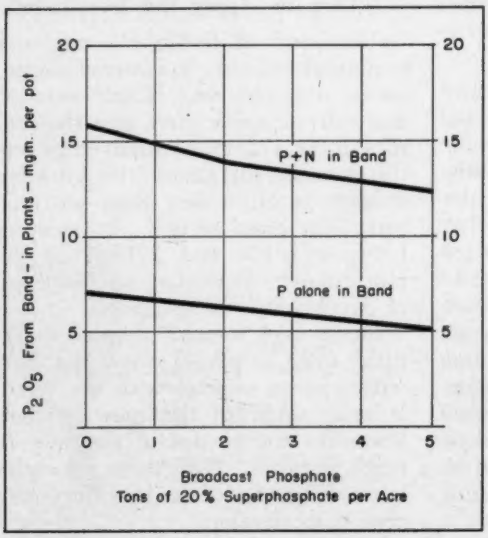

Fig. 1. Effect of broadcast application of superphosphate on the uptake of band applied fertilizer phosphorus by corn. Nitrogen with the phosphate greatly enhanced the uptake of phosphate.

Plant-available phosphate and nitrogen appear to be the two most important ingredients. Phosphate alone is not enough, even though there may be nitrogen at high levels in the rest of the root system. Nitrogen alone is not enough, even though phosphate may be abundant in the rest of the root system.

The combination of the two develops root proliferation. The effect of the nitrogen is shown in the fertilizer recovery figures in a field experiment with corn. Without nitrogen, 8.8% of the fertilizer phosphate was recovered. With nitrogen mixed in the band with the phosphate, the recovery was 14.5%. When nitrogen was placed on one side of the seed and phosphate on the other, the recovery was only 9.9%.

Phosphate Level of Soil Not Important in Phosphate Use from Fertilizer Band

Recovery of phosphate from the fertilizer band is little influenced by the level of phosphate in the soil if there is proliferation of roots within the fertilizer band.

Fig. 1 shows the effect on the uptake from fertilizer band of increasing applications of phosphate mixed through the soil. Additions up to 5 tons of superphosphate per acre mixed in the plow layer had only small effect on the amount of phosphate absorbed from the fertilizer band. This is reasonable since even with extremely high levels of phosphate occurring naturally in the soil or from broadcast applications, the plant-available phosphate in the soil solution is small compared to that found in the fertilizer band. Often it is only one tenth or even one hundredth of that in the band.

Salt Concentrations in Band

A well aerated, moist nitrogen-phosphorus band is an almost ideal place for rapidly developing root surfaces to take up nutrients. Such a zone is an excellent place to put other nutrients required for best starter effects on many soils, such as potassium, minor elements or secondary elements.

Many soils are low in potassium. Potassium in the row fertilizer is an effective means of supplying the early needs of the crop, giving increased early growth and vigor. Broadcast application will not usually meet the seedling needs because roots do not proliferate where only potash is

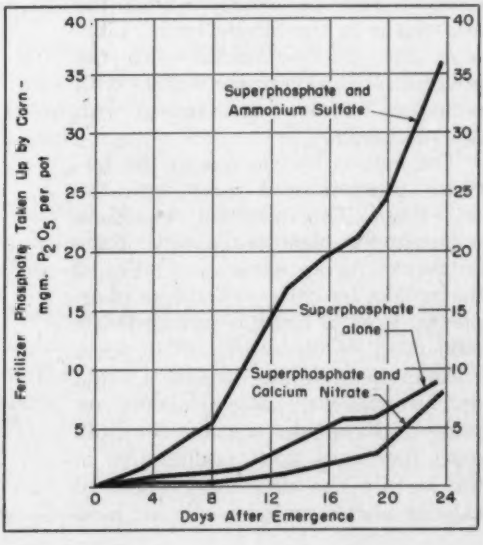

Fig. 2. Nitrogen source effect on phosphate uptake by corn from the fertilizer band. The nitrogen is mixed into the phosphate fertilizer band.

present. The increased concentration in the total soil solution does not compensate for lack of proliferation unless very high rates are mixed throughout the seedling root zone.

Each additional soluble salt will increase the salt concentration in the band, making it a less desirable zone for root development. However, the present accepted limits of salt concentration developed by work on saline soils do not apply much to conditions within fertilizer bands. Data from the West deal with total root systems, whereas with fertilizer bands we are concerned with only partial root system environments.

We have observed root development in bands with consequent efficient uptake of fertilizer under conditions that would have killed the plant if the same situation existed for the total root system. As indicated earlier, it is necessary to keep the band away from the germinating seed or where it might envelop the young seedling.

Within the fertilizer bands a tremendous bit of soil chemistry, fertilizer chemistry, and physiology takes place. The anions may compete with each other. For example, the nitrogen we add to promote root development may compete with the phosphate when the nitrogen is in the nitrate form. Likewise, the chlorine added with the potassium chloride or the sulfate with potassium sulfate may compete with the phosphate.

The cations and anions in the fertilizer compete and react with the soil ions. The resulting equilibria influence the plant availability of the nutrients. As an example, in Fig. 2 the uptake by corn of fertilizer phosphorus from a band is tremendously influenced by the source of nitrogen.

Ammonium sulfate caused a rapid uptake whereas calcium nitrate repressed phosphate uptake. In both cases there was good proliferation in the band. The depressing effect of calcium nitrate probably resulted from anion competition in nutrient absorption, salt concentration, and chemical repression of phosphate availability by the calcium.

Complete understanding of all these variables and appraisal of the intensity of each of the factors will make it possible to develop and bring about more effective use of fertilizer.

Summary

Row fertilizer at planting is concerned primarily with the seedling or formative period. Using corn as an example, there are certain principles of effective nutrient use from fertilizer bands:

1. **The fertilizer must be placed where it will intercept the secondary roots.**
2. **Soluble salts must be kept low around the germinating seeds.**
3. **Placement off to the side of the seed and below seed level is a safe and efficient placement.**
4. **Root proliferation or development in the band is essential since the band occupies a very small part of the root zone.**
5. **Phosphate and nitrogen together are essential for full development in the band.**
6. **Uptake of phosphorus from the fertilizer band is almost independent of the phosphorus level of the soil when the roots develop in the fertilizer band.**
7. **The nitrogen-phosphorus band is an excellent place to add other nutrients required for best early growth on many soils.**
8. **While there is a high soluble salt concentration in the fertilizer band, the roots develop satisfactorily because only a portion of the total root system is in the band.**
9. **In the fertilizer band, there is much competition among various anions and cations—competition we do not yet completely understand.** ◄◄◄

APPLYING FERTILIZER

AMONG ORCHARDMEN, THERE ARE VARIOUS IDEAS ON HOW AND WHERE TO PLACE IT

A SURPRISINGLY large amount of fertilizer is still applied by hand despite recent advances in farm machinery. In New Jersey, for instance, N. F. Childers, of Rutgers University, reports that with tree fruits much of the fertilizer is applied by hand in a 2- to 4-foot band in a ring underneath the outside drip of the branches, the width of the band depending upon the size of the tree. For small trees it may be only 6 to 12 inches wide.

For peach trees where they are planted more closely in the row than between the rows, the lime spreader frequently is used.

In old orchards or mature orchards where the trees cover most of the orchard floor, some growers use the G.L.F. service to apply the fertilizer over the orchard floor from a 6-ton endgate spreader. A few growers are using a Florida citrus grove-type spreader to give an over-all spread on the orchard floor. These machines will apply 200 pounds up per acre.

To do the most good, a fertilizer spreader should apply the fertilizer in a 2- to 4-foot band under the outside drip of the branches.

In general, it is true that roots beneath certain sections of the tree feed those sections of the tree, and if the ground is not fertilized in these areas, then certain portions of the tree are likely to suffer.

If the fertilizer is spread out over the orchard floor, it is necessary to apply considerably more fertilizer per acre in order for the tree to get what it needs from beneath its branches. Fertilizer applied between the rows may have little or no effect on growth of the trees, except possibly indirectly by its effect on the cover crop.

A method of applying solid fertilizer well-liked by some growers is the tractor mounted whirlwind applicator which is driven around the tree to place the fertilizer under the drip of the branches.

At a recent meeting of the New York State Horticultural Society, grower Cameron Garman told of his experience with the Skibbee fertilizer sower which operates on the whirlwind or rotating principle and which costs in the neighborhood of $225. He concluded by saying he believed it saved him more labor than any other tool on the farm.

—*American Fruit Grower*

IMPROPER PLACEMENT LIMITS

- Injury to seedlings by row fertilizers is probably more strongly influenced by placement than by *normal* variations in the kind and amounts of fertilizer used.

- Seed placed two or more inches from the fertilizer was not adversely affected by any of the treatments.

- The very small effects of potash either as the chloride or sulfate observed in these tests suggest that injury caused by potash sources under well-drained soil conditions has been greatly over-emphasized.

- The development and testing of planters on the level, nearly stone-free lands of the Midwest have not produced planters adequate for the uneven land surfaces and stony conditions of the Northeast.

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FERTILIZER and management studies with field corn have demonstrated that high yields depend on adequate plant population.

The production of hybrids with increased standability, the development and acceptance of mechanical harvesters, the availability of commercial fertilizers at a favorable price, and the high "fixed" cost of corn production have pushed optimum stands in Pennsylvania from 10,000-12,000 to 16,000-18,000 plants per acre.

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The average stand in the important corn-producing sections of Pennsylvania is estimated to be around 10,500. Increasing fertility levels with this or a lower population is not likely to cause significant increases, at least with the better corn producers. Conversely, increasing stands without adequate fertility results in little return.

Results from the Jordan Plots in 1956 illustrate this point very well. Half of each plot continued to receive the "original treatment," while the other half received a "corrective" treatment in 1953, based on soil tests,

CROP STANDS

From one of the oldest fertility experiments in the world—the 77-year-old Jordan Plots at Penn State—we get some striking results of proper and improper fertilization practices. Plot 1 received only nitrogen, plot 2 nothing, plot 3 only phosphate, plot 4 only potash, and plot 5 the "recommended treatment," including proper placement and the soil's need for all the elements. Agriculture has come a long way since the Jordan Plots were initiated. And one of the latest strides is the modern farmer's growing concern over how to place his fertilizer to get maximum yields.

past treatment, and previous yields. This side of each plot has been fertilized uniformly since the initial split. Each plot was harvested in 12 subplots—six on the "recommended" side and six on the "original treatment" side. In this way, there were 216 plots which had essentially the same fertility level. The yields from these plots were grouped according to stand, and the groups average:

Plants/acre	Bushels shelled corn/acre
6,000	41
10,000	76
14,000	103
18,000	123
22,000	132

Plots receiving neither phosphate nor manure were treated in a similar manner, with the following results:

Plants/acre	Bushels shelled corn/acre
12,500	35
14,500	38
16,500	47
18,500	31
20,500	40

The hybrid used in these studies was Pa. 602A. It should be emphasized here that the selection of hybrid becomes very important with higher populations and better fertilization practices.

These and similar data show response to higher fertility levels depend greatly on adequate plant density. The data also indicate the extreme variability of the stand at harvest with a uniform planter setting. Stand counts made when the corn was about four inches tall indicated

about 28% fewer plants where recommended fertilizer practices were used. The difference in stand observed was attributed to the starter fertilizer (300 lbs/A of 5-10-10) which was used only on the recommended side.

At a later stage in growth, on plots not receiving the recommended fertilizer analysis, certain areas of the corn exhibited severe phosphate-deficiency symptoms, stopped growing, and, in many cases, died. The appearance of these areas could not be related to soil conditions, and although corn root aphis were feeding on some of the plants, examination failed to reveal insect populations of unusual magnitude.

The condition of the roots suggested a possible disease effect. Dr. C. C. Wernham and his students made isolation studies and found the fungus, *Fusarium monilforme* var. *subglutinous* in the affected roots.

The absence of disease symptoms on the recommended side was believed to be the result of readily available phosphorus contained in the starter fertilizer.

A comparison of yields obtained from adjacent areas on the two sides of the same plot shows the effect of the disorder on yields. (Plot 9)

Area	"Usual" Treatment	"Recommended" Treatment
	Bu/A	Bu/A
1.	62*	133
2.	34*	130
3.	91	137
4.	88	134

* Disorder occurred in part of these two areas.

The examples above, if correctly interpreted, cite beneficial and deleterious effects of starter fertilizer in the same set of plots. The object, then, is to retain the beneficial effects and to eliminate the undesirable.

Hybrid—Fertilizer Rate Study

Unpublished studies conducted by the author in 1951 indicated that a small quantity of fertilizer (5-10-5 used) placed with the seed may retard

This poor stand of soybeans was not caused by poor seed, nor by disease, nor by insects, nor by bad weather—nor by any of the other factors often blamed for such trouble. This stand was extremely limited—or damaged might be a better word—by improper fertilizer placement.

emergence, with the magnitude of the effect influenced by the hybrid used:

Fertilizer Treatment (36" rows) (lbs/A 5–10–5 with seed)	Per cent Emergence (Ave. of 4 varieties, 3 Reps.)	
	9 days*	28 days*
0	85	84
100	81	82
300	68	79
600	32	52

* Days after planting.

Iowa 4059 showed the greatest injury from fertilizer, and Ohio K24 the least injury:

Fertilizer Treatment (lbs/A)	Per Cent Emergence			
	After 9 days		After 28 days	
	Ia 4059	Oh K24	Ia 4059	Oh K24
0	80	84	72	88
100	48	92	56	92
300	56	85	48	99
600	16	39	24	73

Whether the differences found are truly varietal or influenced by seed quality is not known. The late date of planting (June 22) would probably eliminate effects of usual seedling diseases.

Effect of Fertilizer Ratios and Potash Sources On Damage

A more complete study was made in 1956 to compare effects of muriate and sulfate sources of potash and selected ratios of N-P_2O_5-K_2O on emergence and early growth of corn.

Twenty-four fertilizer combinations were used: N levels, 0-15-30-60 lbs. of N/A; P levels, 30-60 lbs. P_2O_5/A; K levels, 0-15-30-45-60-90 lbs. K_2O/A; Mg levels, 30-60 lbs. MgO/A.

The source materials were: N-urea; P-20% super; K-muriate and sulfate; and Mg-$MgSO_4 \cdot 7H_2O$.

The seed and fertilizer were placed by hand. The fertilizer was banded in a single band two inches to the side of the seed. The soil was a deep phase of Hagerstown silt loam. No rainfall was recorded between the time of planting and the first count (7 days after planting). No significant differences were found among rates at the same ratio or between potash sources.

The 0:2:0 and 1:2:1 treatments are somewhat superior from the standpoint of emergence. The effect of starter fertilizers on injury resulting from post-emergence application 2, 4—D agrees with Dr. S. M. Raleigh's greenhouse studies (unpublished) in that nitrogen increased injury, while potash tended to nullify the greater damage due to nitrogen.[1] Conditions for emergence were nearly ideal in this test. The relatively low emergence

[1] Spray and injury ratings made by Dr. Raleigh in this study.

TABLE I. The influence of starter fertilizers of various ratios placed 2 inches to the side of the seed on emergence, early growth and 2,4–D injury of corn (Pa 602A).

Ratios (N–P_2O_5–K_2O)*							
0:2:0	2:2:0	2:2:2	1:2:0	1:2:1	1:2:2	1:2:3	1:2:2:2 (MgO)
Per Cent Emergence (7 days after planting)							
68.8**	59.8**	57.6**	57.2**	65.2	61.2	61.2	55.1
Per Cent Emergence (Maximum)							
75.8	66.0	66.6	63.6	71.0	67.6	65.8	62.3
2,4–D Injury Ratings (Per Cent leaning or broken)							
24	43	37	41	37	35	26	36

* Average of 0-30-0 and 0-60-0 treatment, similarly, the other treatments are the mean of 2 rates e.g. 1=mean of 15 and 30 lbs., 2=mean of 30 and 60, and 3=mean of 45 and 90 lb. rates.

** Average of 10 replications: (1:2:1, 1:2:2, 1:2:3, 1:2:2:2) average of 20 replications.

obtained was partially explained by observed cutworm and bird activity. The seed as selected had nearly perfect germination in laboratory trials.

The lack of definite injury with the very high rates of fertilizer used (equivalent to 600 lbs. of 10-10-10 per acre) was quite surprising and prompted a greenhouse study of materials and placement.

Fertilizer Rate, Ratio, Source, and Placement Study

In this study, flats were partially filled with air-dry soil (Hagerstown silt loam), and the fertilizer materials placed in small furrows made in the soil surface. All materials were ground and mixed just prior to application. Twenty kernels of a single-cross hybrid (Ia L 289 x Ia 1205) were carefully placed in each of the following locations: *(1) directly in the fertilizer band, (2) on the soil surface one inch from the center of the fertilizer band, (3) two inches from the band and (4) three inches from the band.*

The flats were then filled with equal amounts of soil which covered the seed and fertilizer with about one inch of soil. They were watered by a fine spray of a predetermined amount which completely wetted the soil mass but did not allow drainage from the flats. The flats were brought to weight about every third day. Emergence was determined by stand counts made 20 times, starting the eighth day after planting and ending 35 days after planting. A total of 52 treatments was used, occurring largely without duplication.

The materials used were urea, ammonium sulfate, normal superphosphate, and muriate and sulfate of potash. These materials were of commercial fertilizer grade.

The placement of seeds with the fertilizer—regardless of rate, ratio, or source—caused complete inhibition of emergence during the first ten days; where no fertilizer was applied, there was an average of 8.5 plants per row at this time. A few of the treatments are shown in Table II.

With the seed in the row with the fertilizer, all treatments with urea had zero emergence at all time intervals (Rates 15, 30, 60, and 90 lbs. N/A). Treatments with $(NH_4)_2SO_4$ had zero emergence when the rates were 60 or 90 lbs. N/A. Treatments including superphosphate (60 lbs. P_2O_5/A) and nitrogen as sulfate (15 or 30 lbs. N/A), or potash (15, 30, 60, or 90 lbs. K_2O/A) as sulfate or chloride, had from one to six plants emerge.

Table II. Emergence of corn placed in the row with several fertilizers at selected times after planting.

Treatments*				Average Number of Plants from 20 seeds			
N	P_2O_5 (lbs./acre)	K_2O	Source	10 (days)	18 (days)	Maximum	35 (days)
0	0	0		8.5	16	16.5	16
30	0	0	$(NH_4)_2SO_4$	0	4	9	2
0	60	0	Superphosphate	0	9	10	9.5
0	90	0	Superphosphate	0	9.5	10	9.5
0	0	30	K_2SO	0	16	16	14
0	0	30	KCl	0	16	16	13
0	0	90	K_2SO_4	0	10	10	5
0	0	90	KCl	0	6	11	5

* Equivalent to amounts added in single bands spaced 40" apart at these rates in field applications.

When the seed was placed one inch from the fertilizer, much less injury was found. Definite injury was associated with treatments including urea at 60 and 90 lbs. N/A and with the 0-60-90 treatment using KC1. A number of treatments caused slight retardation in emergence.

Seed placed two or more inches from the fertilizer was not adversely affected by any of the treatments.

The cause of the injury by urea is being investigated, since it was greater than could be explained by "salt effect." Soil samples taken at half-inch intervals from the band and subsequent analyses indicated considerable loss of the nitrogen applied as urea. Measurements of soil pH indicated on elevation from about 5.6 to over 7.0 associated with the higher rate of urea treatments. In the author's opinion, these preliminary data suggest the release of free ammonia in the root zone of the seedlings as the cause of the injury.

The very small effects of potash either as the chloride or sulfate observed in these tests suggest that injury caused by potash sources under well-drained soil conditions has been greatly over-emphasized.

General Discussion

The results of the above experiments and general field observations have led the author to some general opinions and conclusions. The tremendous importance of the subject under discussion compels a discussion prior to complete experimental verification.

Probably the most damaging effect of row fertilizers (not directly observable in production fields) is the retardation of emergence and early growth. The plants are particularly susceptible to killing by a number of agents between the time the seed has germinated and the time it has grown too large to be pulled by birds. Seedling diseases, rodents, birds, insects, and the cultivator all take their greatest toll during this period. Retardation of emergence and early growth increases the difficulty of obtaining effective weed control and increases the probability that the corn will pollinate under hot, dry conditions.

Injury to seedlings by row fertilizers is probably more strongly influenced by placement than by *normal* variations in the kind and amounts of fertilizer used. The development and testing of planters on the level, nearly stone-free lands of the Midwest have not produced planters adequate for the uneven land surfaces and stony conditions of the Northeast. It appears necessary to link the seed and fertilizer-placing mechanism so they will not move independently if we are to get a constant and proper seed-fertilizer placement.

Since maximum fertilizer response depends on an adequate stand, all factors and practices contributing to such a stand should be emphasized to the farmer. Unless he has such stands, his acceptance of modern fertilization practices toward full production will be delayed. ◄◄◄

BAND PLACEMENT SUPERIOR

Much work on band placement has been done at Michigan and the results at right are typical. An average of results from two soils shows band placement to be superior (6.2 bushels of corn per acre).

	Increase in yield of corn Bu/Acre
Standard split boot*	3.3
2 inches to the side and 2 inches below*	9.5
*400 lbs. of 3–12–12	
From proceedings of 23rd Annual Meeting of National Joint Committee on Fertilizer Application—1947.	

ABOUT PLACEMENT

WHAT SPECIALISTS SAY

• "For corn and soybeans, I feel that fertilizer placement is quite serious. Each year many cases of damage to stands of these crops are reported and can frequently be traced to improper fertilizer placement."—*F. L. Bentz, Jr., Agronomy Department, University of Maryland.*

• "Damage on individual fields has ranged from little to 50-60% reduction in stands. Damage to this extent seems to occur in almost all cases where high analysis fertilizers are used—about one year in three depending on weather conditions."—*L. J. Cotnoir, Jr., Agronomy Department, University of Delaware.*

• "In my opinion, from 1/3 to 1/2 of the fertilizer applied to row crops in New Jersey is not properly placed for maximum effect."—*E. R. Purvis, Department of Soils, Rutgers University.*

• "Not too serious on potatoes except when we have a dry year but fairly serious on corn."—*J. E. Sheehan, Agronomy Department, University of Rhode Island.*

• "Fertilizer placement is an important problem, especially for corn. At times, only small amounts can be used without 'burning'. At other times, larger amounts are required to cause this damage."—*A. R. Midgley, Department of Agronomy, University of Vermont.*

• "There is no problem in placement of fertilizers for potatoes in Maine. For corn and beans, the situation is quite serious."—*R. A. Struchtemeyer, Department of Agronomy, University of Maine.*

• "Probably more serious than many growers realize.—Improper placement can adversely affect stand resulting in plant populations which are too low to adequately utilize applied fertilizer."—*R. F. Fletcher and G. A. Taylor, Department of Horticulture, Pennsylvania State University.*

• Michigan states: "Apply in a single band 2 inches to the side and 2 inches below the seed level. The split-boot applicator largely used on conventional corn planters is not satisfactory." (Mich. Ext. Bulletin 159).

• Kansas states: "Such bands should be located 1 to 1½ inches to the side of the seed and at about the same depth below the seed. Ordinary split boot applicators on corn planters do not place the fertilizer deep enough." (Kansas Cir. 285).

• Kentucky states: "If the fertilizer attachment places the fertilizer 2 or 3 inches below or in bands 2 or 3 inches to the side of the grain, 300 to 400 pounds may be safely applied." (Kentucky Misc. Publ. No. 10).

• Nebraska specifies placing the starter fertilizer in bands at least two inches deep and about two inches away from the seed. (Nebraska Extension Circular 175).

• "Row crops . . . slow starting and poor stands of tobacco and other crops are frequently due to fertilizer injury . . . place the fertilizer in bands 2 to 3 inches to each side and one to two inches below the seed for minimum fertilizer injury." *North Carolina Agricultural Extension Service.*

• "Fertilizers are more efficiently used by most crops when applied in a band 2 to 3 inches to the side and 2 to 3 inches below the seed . . . avoid putting the seed too close to the fertilizer as germination may be impaired. *Texas Agricultural Extension Service.*

• "Where large amounts of fertilizer are used (especially on crops easily injured by fertilizer such as peanuts), fertilizer should be placed 3 inches to the side and slightly below the seed." *University of Georgia Agricultural Extension Service.*

. . . AND WHY

BECAUSE improperly placed fertilizers may injure seed or young plants resulting in reduced stands, delayed emergence, stunted growth and delayed maturity.

BECAUSE improper placement is, in many cases, limiting the response of crops to fertilizers. Effective placement methods would contribute to greater returns from present fertilizer usage and facilitate even greater and more profitable levels of fertilization.

BECAUSE the problem is becoming more severe as rates and analyses of fertilizers for row crops are increased.

BECAUSE extensive research has indicated that the most effective method of row fertilization is through the use of bands approximately 2 inches to the side and 2 inches below the seed level. A single band placed in this position is satisfactory for corn and many other crops.

BECAUSE effective and relatively inexpensive equipment is now available to band place fertilizers properly. There is no reason why a farmer should continue to be plagued by the effects of poor fertilizer placement practices.

BECAUSE other methods of fertilizer application (broadcast, sidedress, etc.) are used to serve specific purposes. However, these methods are used most effectively in conjunction with properly placed row fertilizer.

Pointers on Placement

Among the regular educational services sponsored by the American Potash Institute are the territorial news letters. These periodic digests, prepared by the Institute's regional managers and field agronomists, cover a variety of topics on soil and crop management.

1 Poor Placement Cuts Response . . .

A recent survey of agronomists and horticulturists in the state experiment stations throughout the Northeast indicated that most potato and many vegetable growers were using fertilizer placement methods which were reasonably effective. However, in many of these states only 5 to 20 per cent of the acreage of other row crops such as corn and soybeans was believed to be planted with effective placement equipment. Furthermore, there was essentially a unanimous belief that improper fertilizer placement is, in a great many instances, limiting the response of those crops to fertilizers—thereby preventing the farmer from realizing the greatest return from his fertilizer dollar. In some areas it was indicated that fertilizer recommendations were not as high as they could and should be if satisfactory placement methods were generally in use.

A recent survey of Midwestern states by the National Joint Committee on Fertilizer Application showed they were overwhelmingly in favor of placing fertilizer to the side of and below the seed when ample amounts of fertilizer were used for corn at planting time.

In the South, North Carolina's Agricultural Extension Service advises farmers slow starting and poor stands (of many row crops) are frequently due to fertilizer injury (from improper placement). And Mississippi's Agricultural Experiment Station says for row crops and for drilled seedings of small grains, sudan-grass, fescue, ryegrass, etc., band placement of phosphate and potash near the seed is much more efficient than broadcasting.

So, it is obvious, under many circumstances improper placement is not only preventing maximum response from fertilizers already in use but is also limiting the use of still higher, more profitable rates of fertilization.

2 Nature of Fertilizer Injury . . .

The effects of improper fertilizer placement may be twofold—(1) The fertilizer may be placed in such a position that the plants cannot utilize the nutrients most effectively. (2) The fertilizer may cause actual injury to the germinating seed or young plants. Primary emphasis will be given to the latter problem since in concentrating the fertilizer near the seed for efficient utilization by the young plants, some injury may result if the

Some issues feature a single important topic, others a variety of research findings and demonstration results being conducted in their territory. In recent months, some of these news letters have featured important trends in fertilizer placement for row crops. The following excerpts are from these letters.

FROM POTASH NEWS LETTERS

fertilizer is improperly placed.

Nitrogen and potash compounds (salts) in fertilizers are, for the most part, quite soluble. Therefore, when they are placed in the soil and become moistened, they dissolve and move up or down in the soil solution depending upon the direction of water movement. Phosphorus compounds are generally less soluble and furthermore are "fixed" by the soil to a certain extent, preventing them from moving about as much as nitrogen or potash compounds.

When large amounts of fertilizer salts dissolve in the soil solution surrounding a germinating seed or young seedling, it becomes difficult for the young plant to utilize this water. In fact, instead of the seed or plant absorbing water, there may even be a loss of water from the plant tissues into the surrounding salt solution. If the surrounding soil solution has a very high concentration of fertilizer salts, the loss of water from the seed or young plant may be so great as to kill it—literally by drying it out—just as effectively as if it had been placed in an oven. Thus, the term, *"fertilizer burn,"* commonly used to refer to this difficulty, is most appropriate. With a lower concentration of salts in the soil solution, the plants may live but may not be able to absorb and maintain sufficient water for normal development. The effect may be a delayed germination and emergence or a stunted condition and slow development of the young plants due to damaged roots.

The concentration of the salt in the soil solution is obviously affected by the amount of the fertilizer salts present and the amount of water to dissolve these salts.

3 Moisture Conditions Affect Damage . . .

The amount of rainfall or soil moisture influences, to a large extent, the degree of damage from improperly placed fertilizer. If the fertilizer is placed in direct contact with the seed and is moistened only enough to cause it to dissolve, giving a concentrated salt solution around the seed, conditions are favorable for maximum fertilizer damage.

If the fertilizer is placed immediately under the seed (1 to 2 inches) and the soil is wet down just enough to bring the fertilizer salts into solution, there may also be severe fertilizer burn. As the soil dries, the salts move upward in the soil solution—

again bathing the germinating seedlings with the concentrated salt solution.

If there is still heavier rain following planting, the fertilizer salts will dissolve and move down to greater depths in the soil with the leaching water. Nitrate forms of nitrogen and other anions such as chlorides and sulfates will tend to leach more readily than will the ammonium nitrogen or the potassium which are attracted to the soil colloids. If these salts are not leached to the water table, they will move back up as the soil dries.

However, by this time they are greatly dispersed so that their concentration is usually not great enough to cause serious damage. Furthermore, by this time the seed may have already germinated and be beyond the point where severe damage could occur. This explains how under proper moisture conditions, there may be little or no damage from improperly placed fertilizers. Obviously, moisture conditions have a great effect upon the degree of damage.

Problem Becoming More Critical . . .

The problem of improper fertilizer placement with row crops is not a new one. However, it is becoming decidedly more serious.

In 1949, just 8 years ago, 2-12-6 was the most popular fertilizer grade in the Midwest. In 1957, such grades as 4-16-16 and 5-20-20 will be among the most popular for corn. The 2-12-6 has a total of 8 units of N plus K_2O while the 4-16-16 and 5-20-20 have 20 and 25, respectively. Thus, in the last few years the concentration has tripled. Too, in the same period of time the pounds of fertilizer applied at planting have increased greatly.

The following figures illustrate how both the analysis and rate of fertilizer application have increased in the northeastern United States during the past twenty years.

Year	Average Analysis of Mixed Fertilizers in the Northeastern United States			Plant Food Usage in Northeast Lbs/A of Harvested Crops		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
1935	3.7	9.7	7.2	4.8	13.3	7.2
1955	5.5	11.5	10.6	17.6	34.2	29.7

Despite the fact we are using approximately 2½ to 4 times the amount of plant food per acre today as we used twenty years ago, in the Northeast placement methods have changed little with most crops. With some exceptions, farmers are still using equipment and techniques which allow much of the fertilizer to come in contact with the seed at planting.

And in the South, the picture seems quite similar. While the analysis of fertilizers has grown, the following figures show how the rate of fertilizer application has increased in just two decades:

Year	Plant Food Usage in South Lbs/A of Harvested Crops		
	N	P_2O_5	K_2O
1935	3.6	5.8	3.0
1955	20.9	19.7	17.3

Many people have blamed concentrated or high analysis fertilizers for the increasing amount of fertilizer damage. However, concentrated fertilizers as such are not necessarily responsible for this difficulty. In fact, there is usually less damage from high analysis than from low analysis fertilizers where *equal* amounts of *plant food* are used. The real cause of the trouble is the fact that there has been little improvement in placement methods as rates of fertilizer usage have increased.

5 Proper Placement—Methods . . .

The importance of placing the planting fertilizer in a band to the side of and below the seed has been recognized for a long time. Much experimental work has been conducted in the past twenty-five years. In 1948 the National Joint Committee on Fertilizer Application released a publication, *Methods of Applying Fertilizer,* "When a high amount of nutrients is to be applied at corn planting time it should be drilled in a continuous band approximately 2 inches to one side of the row and about two inches below the level of the seed." The Committee also states that when soybeans are planted on soils deficient in available nutrients, "the fertilizer should be broadcast and plowed under . . . or placed in a band 2½ inches to each side of the row and 2 inches below seed level."

In many states, recommendations are made for maximum amounts of soluble salts ($N \div K_2O$) at planting for a row crop such as corn. Split boot placement is the standard in such recommendations. Maximum amounts would be somewhat higher if single band placement were used.

It is generally recognized now that, with our present rates of fertilizer, a band on one side of the row is as effective as a band on each side of the row.

With heavily fertilized crops such as potatoes, tobacco, and certain vegetables, however, better results have in many cases been obtained with fertilizer banded on both sides of the seed or plants.

The necessity for band placement on vegetable crops has long been recognized. A large quantity of high analysis fertilizer is usually applied, much of it at planting. In contrast to field crop growers, however, many of the vegetable growers are using band placement equipment. A summary of results on white potatoes from several states was made several years ago.

Fertilizer Placement	*Yield of potatoes Bu/per Acre*
In row with seed	304
Two inches to the side and two inches below	348

Relatively large amounts of fertilizers can be applied satisfactorily at planting using banded side-placement techniques. Rates of 1,500-2,000 lbs. per acre are commonly applied to vegetables and potatoes with good results. E. R. Purvis of the Soils Department at Rutgers reported no injury to corn from the use of 1,000

lbs. of 14-11-11 placed 2 inches to the side and 2 inches below the seed at planting. In using high rates, however, it is extremely important that the fertilizer be placed *precisely*. This means the use of the right kind of equipment, properly adjusted and operated.

There are many situations where other placement methods may be used effectively in conjunction with row fertilization. Where side-placement equipment is not available, many states recommend a split application with a part of the total fertilizer being applied broadcast before planting or sidedressed after planting—with remainder applied at seeding. Several states, for example, recommend that for field crops like corn, the fertilizer should be broadcast or drilled in before planting except for 150-300 lbs. of the recommended grade which is applied with the planter.

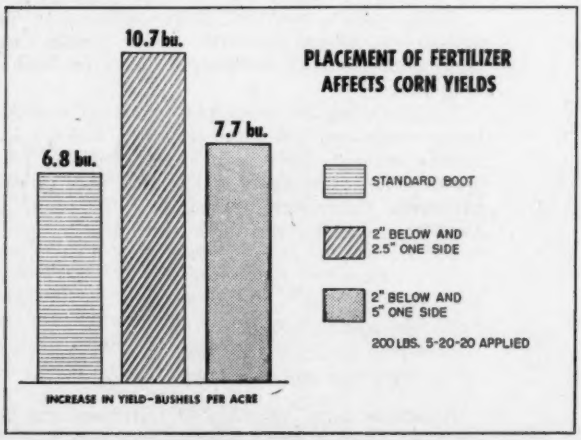
If small rates of fertilizer are being used on soils of low fertility, side-placed row application is definitely superior to broadcast application. For example, in recent work, S. E. Younts of the Agronomy Department of Cornell obtained a 7.6-bushel greater increase in yields of corn from 20 lbs. K_2O applied in bands to the side of the seed than where the same amount of potash was broadcast before planting. Even at higher rates of application there was a tendency for the banded row placement to be superior to broadcast application on this soil.

Under low fertility levels, it often is desirable to broadcast relatively large amounts of phosphorus and potash to build up the level of fertility. This should be followed by more moderate annual applications at planting. Even if the fertility level of the soil is high, it is important to apply some "starter" fertilizer near the seed in order to give the young plants a fast start.

For some crops it is desirable to apply a part of the fertilizer as a sidedressing during the growing season. This is particularly true in the application of nitrogen and potash on the lighter, sandier soils.

BAND PLACEMENT SUPERIOR—AGAIN

Work by MacGregor and Johnson in Minnesota illustrates the importance of single band placement on corn at right. Proper placement (2" below and 2.5" one side) gave 3.9 bushels more corn than the standard split boot. This increase may be due to less salt damage or to placing the phosphorus in a more accessible position. In dry years the difference would be even greater, either because of a more concentrated salt solution in the zone of seed germination with the split boot or because the phosphorus was out of the zone of root activity.



Above: Two hundred pounds of 5-20-20 increased corn yields 6.8 bu. when the split boot was used. With single band placement 2 inches below and 2.5 inches to one side, the increase was 10.7 bu. (two-year average in Minnesota).

The following article reprints on profitable soil and crop management are available on request. Please indicate the reprint code and the number you desire. The address is: American Potash Institute, 1102 16th Street, N. W., Washington 6, D. C.

SOIL AND PLANT ANALYSIS

Y-5-43	Value & Limitations of Methods of Diagnosing Plant Nutrient Needs
CC-12-52	The Leaf Analysis Approach to Crop Nutrition
DD-10-53	Sampling Soils for Chemical Tests
K-2-54	Soil and Plant Analyses Increase Fertilizer Efficiency
JJ-10-54	Principles Involved in Soil Testing

FORAGE CROPS

Z-5-45	Alfalfa—The Aristocrat
II-12-51	Pasture Improvement with 10-10-10 Fertilizer
I-2-53	Sericea Is a Good Drought Crop
N-4-53	Coastal Bermuda — A Triple-threat Grass on the Cattleman's Team
T-5-53	Trefoil Is Different
II-11-53	The Importance of Legumes in Dairy Pastures

GENERAL FIELD CROPS

A-1-52	Research Points the Way to Higher Levels of Peanut Production
Y-10-52	The Nutrition of Muck Crops
J-3-53	Balanced Nutrition Improves Winter Wheat Root Survival
P-4-53	Learning How to Make Profits from Sweet Potatoes
U-4-54	Nutrient Balance Affects Corn Yield and Stalk Strength
LL-10-54	Relation of Fertilizer to Quality and Yield of Flue-cured Tobacco
C-1-55	Summary of Ten Years' Work with Complete Fertilizers on Sugar Cane

VEGETABLE CROPS

SS-12-49	Fertilizing Vegetable Crops
SS-11-54	Foliar Application of Plant Nutrients to Vegetable Crops

FRUIT AND NUT CROPS

P-3-45	Balanced Fertility in the Orchard
BB-8-50	Trends in Soil Management of Peach Orchards
X-8-51	Orchard Fertilization Ground and Foliage
EE-8-54	Red Apples Require Balanced Nutrition
J-4-56	The Relation of Potassium to Fruit Size in Oranges

SOILS AND FERTILIZER—GENERAL

3-1-56	Potash in Agriculture
A-1-44	What's in That Fertilizer Bag?
T-4-46	Potash Losses on the Dairy Farm
TT-11-47	How Different Plant Nutrients Influence Plant Growth
AA-6-48	The Chemical Composition of Agricultural Potash Salts
JJ-11-53	Boron—Important to Crops
R-3-54	Soil Fertility (Basis for High Crop Production)
YY-12-54	Physical Condition of the Soil Affects Fertilizer Utilization
D-1-55	Nitrogen Use Accentuates Need for Minerals

GENERAL

S-5-40	What Is the Matter with Your Soil?
Y-5-46	Learn Hunger Signs of Crops
GG-10-48	Starved Plants Show Their Hunger
BB-10-51	Healthy Plants Must Be Well Nourished
KK-12-51	Potassium in Animal Nutrition
CC-6-54	Fertility Increases Efficiency of Soil Moisture
A-1-55	Potash-Deficiency Symptoms

Abstracts

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Apples—Soil or Foliage Fertilizer Placement
Beattie, J. M.
Soil vs. foliage applications of potassium fertilizers to apples. Ohio Agr. Exp. Sta. (Wooster) Spec. Cir. 93, p. 16-18. Sept. 1956. (Current results in fruit research).

With the increased use of N fertilizers, and with certain sites being used for 2nd and 3rd generation orchards, the occurrence of K deficiency on apples in Ohio is becoming widespread. Results from tests indicate that foliage sprays of K are of greatest value as a temporary measure for correcting K deficiency. For long-range correction of the deficiency, soil applications of KCl at the rate of ¼ lb. per year of tree age for apple trees up to 10 years of age or applications of 4 lb. per tree for older trees are suggested. Response from applications of K is anticipated when the K content of the median shoot leaves falls below 1% of the dry weight during the latter part of July.

Fertilizer Placement—on Yield of Swedes, Turnips, Peas, Beans, and Potatoes
Russell, E. W.
The Placement of Fertilizers. Royal Agrl. Society of England Jour. 116: 117-124. 1955.

Discussion is given on experiments conducted at the Maculay Institute for Soil Research at Aberdeen on effect of fertilizer placement on the yield of swedes, turnips, peas, beans, and potatoes. Results are tabulated. Placing 60 lb. per acre of K_2O underneath the seed of swedes gave rather lower yields than broadcasting it, though if it was placed to the side of the seed it did no harm. For peas and beans, a greater profit was obtained when fertilizer was placed than when it was broadcast. For potatoes it is recommended that fertilizer be placed in a side band. Fertilizer sown in contact with the seed has given better yields than broadcasting over the surface immediately after planting.

Placement Method—The Difference
Davis, J. F. and Shepherd, L. N.
Method of applying fertilizer makes yield difference. Croplife 3(44): 2. Oct. 29, 1956.

In muck soil tests conducted by soil scientists at Michigan State University, the method of application made as much as 103% difference on onion yields and up to 50% on spinach yields. If more than 800 lb. per acre of a fertilizer like 5-10-20 is to be applied with row spacing of 16-18 inches, the excess should be put on ahead of planting with a fertilizer grain drill, be broadcast on the surface, or plowed under. The researchers think that a good way to fertilize the crops is to put the N and P in a band two inches below the seed and broadcast the K.

Band Placement for Forage Crops
Accurate placement of seed, fertilizer key to pasture establishment, USDA tests show. USDA News Release No. 873-57, 2 p. March 18, 1957.

Placement of fertilizer and forage seeds in separate "bands" within the seedbed may prove to be the farmer's trump card in establishing a good pasture. Results of experiments conducted since 1952 at Beltsville, Maryland, indicate that the most effective method of forage-plant establishment was a combination of drilling fertilizer 1¼ inches deep and seed ¼ inch deep. Phosphoric acid and complete fertilizer stimulated early growth of orchardgrass and Sericea lespedeza, but recent results seem to indicate that applications of N or K, alone or in combination, are apparently detrimental to germinating seeds and seedlings. USDA researchers point out that considerable work remains to be done on fertilizer ratio, fertilizer placement, degree of precision necessary and type of band-seeding machinery that gives best results.

Corn—Fertilizing at Row
Corder, G. D.
Fertilizing corn at the row. Ky. Agr. Ext. Serv., Timely Notes on Soils & Crops, p. 4-5, Feb. 1957.

An application of fertilizer at the row will be quite beneficial on nearly all corn land in Kentucky. However, more and more farmers are reporting poor stands of corn which may be resulting from heavy application of fertilizers at the row. For best results, no more than 40 lb. N, plus K_2O should be placed with or near the seed. If seed and fertilizer are placed a full 2 inches apart, row applications can go as high as the farmer wishes.

Fertilizer Placement for Corn
Seay, W. A. and Doll, E. C.
How to grow corn profitably in Kentucky. Agrl. Ammonia News 7(1): 50. Jan.-Feb. 1957.

Since fertilizer is often one of the principal costs in the production of high yields of corn, much care should be exercised in buying the correct kind and amount of it. On soils which test very low in P and K, as much as 100-120 lb. each of N, P_2O_5, and K_2O are needed. Small applications of fertilizer are best applied in the row, but not more than 200 lb. per acre of fertilizer should be applied with a distributor that puts the fertilizer with or near the seed. Potassium can be applied as a sidedressing, but it is better to apply it before or during planting.

Hobbs, C. H.
Studies on mineral deficiency in pine. Plant Physiol. 19(4):590-602, illus. Oct. 1944.

Deficiency symptoms were induced in pitch, red, white and shortleaf pine seedlings grown in quartz sand cultures in crocks placed in a greenhouse and supplied with nutrient solns. differing in their contents of N, P, K, and Mg. K-deficient pines were usually bluish-green in color and exhibited considerable necrosis. Pitch and shortleaf pines—rapidly growing species—developed necrotic terminals which became characteristically copper-colored. White pine seedlings showed a general chlorosis, a condition entirely lacking in the other three pines. N, P, and K deficiencies were accompanied by great reductions in growth as measured by height of top, stem diameter, and dry wt. of tips and roots. Mg deficiency was not accompanied by as great reductions as were other three deficiencies.

Crowther, E. M.
Nutrition problems in forest nurseries. Gr. Brit. Rothamsted Exp. Sta. Ann. Rept. 1952, p. 44. 1953.

Acute general yellowing of transplants on plots known to be K-deficient was observed at Wareham for 1st time since 1946. Usual purplings from K deficiency were general on plots lacking this element in certain compost and fert. treatments.

Denuyl, D.
Forest plantations, their establishment, growth and management. Ind. Agr. Exp. Sta. Cir. 331, p. 18. Feb. 1948.

On soils of low fertility the initial growth of black locust seedlings can be increased by using fertilizer. One tablespoonful of 2-12-6 fertilizer should be placed in the hole at time of planting. Experiments have shown that the height and diameter growth of fertilized seedlings is more than twice that of non-fertilized seedlings. The root development of fertilized trees is five times that of non-fertilized trees. Experiments have also shown that fertilizing coniferous seedlings or transplants at the time of planting, using the same technique as described for black locust, has not proved successful.

Nemec, A.
Nutritional disturbances of dead fir stocks. Forstwiss. Centr. 62:245-253. 1940. *Abs.* C.A. 35(20):7092. Oct. 20, 1941.

Anals. of bark and wood of sound and dead trees for ash, N and various mineral constituents were made. Most marked dif. in the mineral contents between sound and dead trees was exhibited by K_2O content; in the former, it increased several fold above a ht. of 3-4 m. in contrast to a fairly constant content throughout for the latter. Further exps. are necessary to determine whether the observed disturbance of the mineral nutrition of the dead trees is the cause or a result of their death.

Kopitke, J. C.
Effect of potassium oxide salts on the hardening of coniferous seedlings. J. Forestry 39:555-558. 1941. *Abs.* C.A. 35(21):7621. Nov. 10, 1941.

Effect of K_2O fertilization on the properties related to hardening of white spruce, red pine and white pine seedlings was studied in quartz sand cultures and on sandy nursery soils in northern Wis. Appls. of such ferts. promoted accumulation of simple and invert sugars in the tissue of seedlings, increased content of total solids and the osmotic pressure and lowered the f.p. of the expressed sap. All of these changes indicate a marked improvement of nursery or planting stock to withstand frost injury. Frequent anals. of nursery soils and timely correction of K_2O deficiency are prerequisites for production of frost-resistant nursery stock. Appls. in amts. higher than 300 lb. K_2O per acre had a pronounced unfavorable effect.

Kopitke, J. C. and Wilde, S. A.
Potash and frost resistance. 56th Ann. Rept. Wis. Agr. Exp. Sta. 1939, Pt. II, (Bul. 449), p. 18. Mar. 1940.

Adequate potash fertilization increases the frost resistance of forest nursery stock. Indications are that maximum benefit from potash fertilizers may be obtained by applying them early in the season in amounts not exceeding 300 lb. of potassium oxide per acre.

The station agent from the small western town was making his first trip to New York City. He was interested in seeing the seals in Central Park and the skyline, but the great moment of the visit was to be his appointment with the lawyer for his railroad whose offices were in the Empire State Building.

The lawyer was a big man and a busy one and he could not help being a little surprised when the agent did not arrive for the interview. It was not until nearly two hours later that a faint knock was heard on the door, and the little agent limped in.

"What a climb," he gasped as he collapsed into a chair. "Eighty flights of stairs."

"Good heavens, man," exclaimed the lawyer, "why didn't you take the elevator?"

"Well, I planned to," said the agent, "but it pulled out just as I got there."

* * *

"There I was, forced down on a desert island with a lovely blonde."

"What did you do for food?"

"Darned if I can remember."

* * *

Mountaineer: "What'll my boy learn in this here school, teacher?"

Teacher: "History, spelling, trigonometry . . ."

Mountaineer: "Give him lots of that there triggernometry—he's the worst shot in the family."

The elderly stock broker, age 75, carried his 19-year-old bride over the threshold. He introduced her to his household staff, and later asked his chauffeur what he thought of the new mistress. The chauffer replied, "She's a beautiful young lady, sir, but I hate to see a man start out on a day's work so late in the afternoon."

* * *

Two Negroes were discussing family trees.

"Yessuh, man," said Ambrose, "I can trace mah relations back to a family tree."

"Chase 'em back to a family tree?" asked Mose.

"Naw, man—trace 'em—trace 'em —get me?"

"Well, there ain't but two kinds of things dat live in trees—birds and monkeys—and yo' sho' ain't got no feathahs on you."

* * *

The lady in the row ahead had talked to her companion during the whole movie, especially during the exciting parts. The man behind her could restrain himself no longer. He tapped on her shoulder:

"You've talked through this whole show, lady. I think you're an ill woman. You ought to go to your doctor right away and have a yapendectomy."

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1. N-5-56 Fertilizer placement for Corn in Minnesota
2. M-5-56 The Placement of Fertilizer for Peanuts
3. SS-11-54 Foliar Application of Plant Nutrients to Vegetable Crops
4. H-3-56 The Application of Fertilizers in Irrigation Waters
5. H-3-57 Lime . . . Its Placement & Penetration in Soils

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